# Sewage Works Journal

**Published by**

**Federation of Sewage Works Associations**

**Lancaster, Pa.**

Copyright, 1946, by the Federation of Sewage Works Associations, Inc. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

**Vol. XVIII** **November, 1946** **No. 6**

**Sewage Works:**

Digested Sludge—An Aid to the Activated Sludge Process. By L. S. Kraus ..... 1099

Modernization of the B.O.D. Test for Determining the Efficacy of Sewage Treatment Processes. By Clair N. Sawyer and Leland Bradney ..... 1113

Precaerated Raw Sludge Recirculation Increases Primary Sedimentation Efficiency at Denver. By C. P. Gunson ..... 1121

Control of Sewer Usage at Detroit, Michigan. By Clyde L. Palmer ..... 1127

The Effects of Copper-Bearing Wastes on Sludge Digestion. By H. T. Rudgal ..... 1130

The Transmission of Disease by Sewage. By R. N. Clark ..... 1138

Effects of Ground Garbage on Sewage Treatment Processes. By Willem Rudolfs. 1144

Sewage Treatment at an African Native Community. By R. S. Young, A. J. Hall and A. W. Darvall ..... 1151

**Industrial Wastes:**

Treatment of Sulfite Waste Liquor on High Rate Trickling Filters. By R. G. Tyler, William Maske and Robert Brewer ..... 1155

A Study of Wastes From the Synthetic Rubber Industry. By O. R. Placak and C. C. Ruchhoft ..... 1169

**The Operator's Corner:**

What Every Citizen Should See ..... 1182

Ingenuity—Tool of the Operator. By R. W. Simpson ..... 1182

Small Plant Operation. By Herbert O. Johnson ..... 1191

Facts About Chlorine. By Wilmer H. Koch ..... 1194

Bark From the Daily Log. By W. W. Mathews ..... 1198

Interesting Extracts From Operation Reports. Conducted by LeRoy W. Van Kleeck:

Summary of Plant Operations for the Year 1944 of the Greater Winnipeg Sanitary District, Winnipeg, Manitoba. By D. L. McLean ..... 1202

Report of Operation of the Willow Run Bomber Plant, Detroit, Michigan Sewage Treatment Plant for the Years 1943 and 1944. By N. Herda ..... 1205

Report of Operation of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1945. By Ralph E. Fuhrman ..... 1206

Thirteenth Annual Report of the Green Bay, Wisconsin Metropolitan Sewerage District Commission for the Year Ending March 31, 1945. By George Martin ..... 1208

Annual Report for the Year 1944 of the Bureau of Sewers of the City of Worcester, Mass. By John H. Brooks, Jr. ..... 1210

Tips and Quips ..... 1211

**Editorial:**

Industrial Wastes Activity in the Federation ..... 1217

**Proceedings of Member Associations:**

Alabama Water and Sewage Group Organizes ..... 1219
Florida Sewage Works Association ..... 1219
New Jersey Sewage Works Association ..... 1220
New Member Association Proposed at Inter American Sanitary Engineering Conference ..... 1222
New York State Sewage Works Association ..... 1225
Ohio Conference on Sewage Treatment ..... 1226
Pacific Northwest Sewage Works Association ..... 1227
Member Association Meetings ..... 1229

**Federation Affairs:**

I Knew Arthur Bedell. By Morris M. Cohn ..... 1230
Nineteenth Annual Meeting a Great Success ..... 1232

**Reviews and Abstracts:**

Sedimentation and the Design of Settling Tanks. By Thomas R. Camp. Discussions by Norval E. Anderson, R. A. Mulholland, P. Charles Stein, Lynn Perry, E. Sherman Chase and Rolf Eliassen ..... 1236
Dewatering, Incineration and Use of Sewage Sludge. Discussions by C. R. Velzy, George J. Schroepfer ..... 1238
Computing Coagulant Requirements in Sludge Conditioning. Discussions by Paul D. McNamee, D. L. McLean, K. Franschina, and Walter H. Brown ..... 1238
Concentration of Sewage Sludge. Discussion by C. R. Velzy ..... 1240
Gas Engine Power for Sewage Treatment Plants. By Allen J. Burdoin ..... 1240
Disposal Plant to Alleviate Boston Harbor Nuisance. By Karl R. Kennison ..... 1241
Practical Aspects of Sludge Treatment at the Yardley Works of the Birmingham Tame and Rea District Drainage Board. By Norman Salt ..... 1242
Wartime Treatment of Sewage and Sludge Disposal. By F. Oliver ..... 1244
Treatment and Disposal of Waste Waters Containing Chromate. By J. Grindley ..... 1244
Disposal of Petroleum Refinery Wastes. By W. B. Hart ..... 1245
I. Industry's Relation to the Problem ..... 1245
II. Industry and the Authorities ..... 1246
III. Refining Industry Has Important Role in Water Conservation Program ..... 1246
IV. Proper Classification of Wastes First Step in Disposal Problem ..... 1246
V. Properties of Surface Waters Affected by Refinery Wastes ..... 1248
VI. Waste Oils Escaping to Surface Waters May Cause Many Kinds of Damage. 1248
The Effect of Mining (Coal) Subsidence on Sewers and Sewage Disposal Works in the West Riding of Yorkshire. By J. H. Garner ..... 1249
Industrial Waste Problem to be Solved ..... 1250
The Preparation and Nature of Town's Refuse Sewage Sludge Composts. By C. Bould ..... 1250
The Failure of Poliomyelitis Virus to Grow in Certain Protozoa of Sewage. By C. A. Evans and K. L. Osterud ..... 1253
Control by D.D.T. of Flies Breeding in Percolating Sewage Filters. By T. G. Tomlinson ..... 1253
Investigation of Plant Growth Substances (Auxins) in Sewage Products. By C. A. Chaplin and C. J. Regan ..... 1254
Grand Forks Water and Sewage. By K. W. Riley ..... 1254
Modern Design Trends for Sewage Treatment. By Kenneth V. Hill ..... 1254
Washington State Sewerage Systems and Sewage Treatment and Disposal Systems... 1255
Current Developments in Waste Utilization. By Harold R. Murdock ..... 1256

Author Index ..... iii
Subject Index ..... vii
Index by Place ..... xv

# Sewage Works

## DIGESTED SLUDGE—AN AID TO THE ACTIVATED SLUDGE PROCESS *

By L. S. Kraus

*Chemist, The Greater Peoria Sanitary and Sewage Disposal Dist., Peoria, Ill.*

In a previous paper (This Journal, **17**, 6, 1177) a basis for the application of digested sludge to the activated sludge process was presented.

The most satisfactory activated sludge plant operation is brought about with an activated sludge in which the sludge index is maintained within relatively narrow limits. The volume of return and waste activated sludge required to be handled is found to be approximately directly proportional to the sludge index. If a plant is equipped with sufficient pumping facilities, and the hydraulics of the pipe lines and conduits will permit handling the volumes required, loss of activated sludge in the final effluent can be kept under control until the velocities in the final settling tanks are such that turbulent conditions prevent settling of the activated sludge.

More difficult to control is the waste activated sludge. Assuming that the pumping and storage facilities are adequate, the factor limiting the ability to maintain the system solids balance required by the sludge index of the activated sludge is the efficiency of the primary settling tanks or other concentration tanks to settle the wasted sludge. As the efficiency of removal of solids from these tanks decreases the suspended solids added to the activated sludge system increases. This necessitates the wasting of more sludge from the activated sludge system and further decreases the efficiency of the settling tanks or the activated sludge concentration tanks. The vicious cycle so produced causes the sludge index to further increase.

If the sludge index is allowed to increase to the point of breakdown of either of the facilities noted, or if pumping facilities are not adequate, the system balance will fail and sludge will be lost over the final settling tank weirs. When this takes place the only corrective measures are to by-pass primary settling tank effluent or to lower the sludge index of the activated sludge.

### The Bulking Problem at Peoria

Due to nature of the mixture of domestic sewage and industrial wastes containing soluble materials treated at the Peoria sewage treatment works, the activated sludge was in a practically continuously bulked condition. Table II (Period A) indicates the condition of the activated sludge in a 4-month period immediately preceding the use of digested sludge to correct this bulking difficulty. Note that 75.4 per cent of the time the sludge index (Mohlman) was above 200 and 50.9 per cent of the time it was above 250. During this period it was possible to operate the process without losing sludge over the weirs in the final settling tanks until the sludge index reached 350. When this value was attained it was necessary to by-pass part of the primary effluent. The sludge index during this period was above 350 for 15.4 per

* Presented at the 18th Annual Meeting, Central States Sewage Works Assn.; Lafayette, Ind.; June 13–14, 1946.

cent of the time and this resulted in by-passing 7.9 per cent of the primary effluent.

It should be noted here that during this period of operation, reaeration of the activated sludge was employed, and that return sludge rates were adjusted carefully on the basis of mixed liquor settling tests every two hours. This was done in such a manner that the suspended solids in the return sludge from each final settling tank would not exceed the value indicated in the settled sludge after thirty minutes in the liter graduate settling test.

At this time it was thought that the bulking condition was brought about by shock industrial loads, and consideration was being given to means of reducing the shock loads and also to methods of reducing the effect of these loads on the activated sludge. It was apparent from the mathematics of the process that a vicious condition existed in the activated sludge system. During periods of high sludge index it was necessary to reduce the suspended solids in the mixed liquor and in the activated sludge in the reaeration tank in order to maintain the return sludge suspended solids at the concentrations indicated in the settling tests. It had been observed that under these conditions activated sludge of very high sludge index was being synthesized and that this material, when added to the relatively small amount of solids in the system, produced major overall changes in the mass of the sludge. The first step toward the solution to the problem appeared to be the maintenance of large amounts of activated sludge in the system in order that the rate of change in density of these solids should be minimized.

In addition it had been noted that storm flows lowered the sludge index of the activated sludge, and this was considered to be brought about by the addition of materials of high density to the activated sludge, and also by reducing the amount of high sludge index solids produced by reducing the soluble material in the sewage from which these solids were synthesized.

These and other considerations noted in the previous paper led to laboratory and plant scale experiments which revealed that digested sludge solids could be converted into activated sludge solids rather readily, and that the activated sludge so produced would be one of low sludge index. This could be accomplished by mixing digested sludge with activated sludge and aerating the mixture with sufficient air for an adequate period of time.

It was also found that when the activated sludge so produced was mixed with an activated sludge of high sludge index the resulting sludge index was the weighted average of the two sludge indices.

## The "Interchange" Procedure

Thus is established the basis of a procedure for controlling the sludge index of activated sludge—first to produce an activated sludge of low sludge index by adding digested sludge to activated sludge in an aeration tank and aerating the mixture until the whole is converted to an activated sludge, and then adding the low sludge index activated sludge so formed to a high sludge index activated sludge in the aeration tanks in such a manner that a desired condition of mixed liquor suspended solids be maintained. The procedure of mixing the two activated sludges will be referred to herein as an "interchange."

The simplest method of accomplishing this procedure is that of continuously adding the required amount of digested sludge and part of the return activated sludge to an aeration tank, and continuously displacing an activated sludge of low sludge index from this tank and adding this to the return activated sludge. The flow diagram of the process is indicated in Figure 1.

V.18
1946

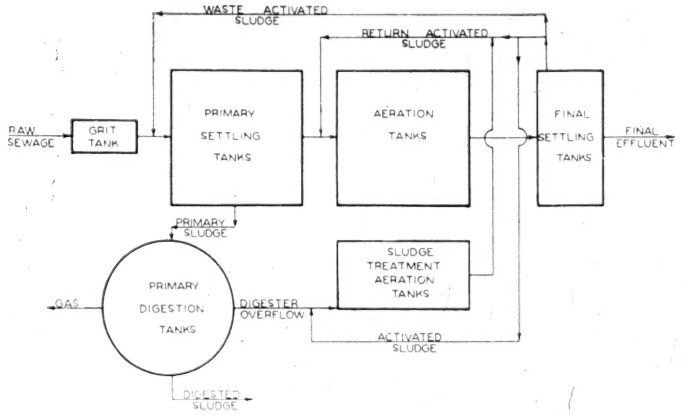


**FIGURE 1.—Flow diagram of process during continuous addition of digested sludge and continuous interchange.**

In this process it may be noted that the digested sludge is added in the form of digested overflow from the primary digesters. This source of digested sludge is used because of ease of operation. Bottom sludge from the secondary digesters was used successfully, but due to operating schedule problems this source did not lend itself to the most satisfactory procedure. The digester overflow is mixed with return activated sludge from the final settling tanks and the mixture is aerated in the sludge treatment aeration tanks; the overflow from these tanks is then added to the normal return activated sludge to the aeration tanks. While this procedure was carried out on full plant scale operation and was successful in controlling the sludge index, it did not remedy one of the other difficulties that frequently caused trouble in the activated sludge process.

Due to the many industrial wastes entering the sewers and to the lack of operating care in some of the industries, large quantities of organic wastes are occasionally discharged to the sewers, and these shock loads on the plant cause the activated sludge to lose its clarifying properties. When this took place during operation with the conventional activated sludge process, it would take as long as ten days before the activated sludge returned to normal clarifying ability, and occasionally another shock load would be imposed on the activated sludge before clarification was re-established. When a shock load was experienced during the period of continuous addition of digested sludge and continuous interchange, all of the activated sludge lost its clarifying property to the same degree as in the normal process.

In order to reduce the effect of shock loads, a procedure was developed whereby the interchange process was made intermittent. The digested sludge was added continuously to the sludge treatment tank and an interchange of the activated sludge in the aeration tanks with the activated sludge in the sludge treatment tank was made at a high rate over a 6-hr. period each day. This materially minimized the probability of subjecting the activated sludge in the sludge treatment tank to shock loads, and resulted in a very satisfactory operation except that, due to the high rate of interchange, a considerable concentration of nitrate nitrogen was

introduced into the aeration tanks and this caused some difficulty in controlling rising sludge in the final settling units.

The intermittent interchange was then altered to a low rate interchange, and the lower concentration of nitrate nitrogen present in the mixed liquor did not cause the activated sludge to rise in the final settling tanks. The interchange was extended over a period of 24 hours so that a procedure was established whereby the aeration tank activated sludge was used to purify the sewage in the normal manner for one day, and then this sludge was interchanged with the sludge treatment tank activated sludge on the following day. This manner of operation resulted in excellent control of the sludge index and rapid recovery of the clarifying property of the activated sludge following the application of shock loads.

## Operating Data Periods

For the purpose of studying the efficacy of this process, data for three periods, each of four months duration, are presented.

Period A represents the four months immediately before using this process. During this time one-fourth of the aeration tank capacity was given over to reaeration of the return sludge. Normal aeration tank effluent settling tests were determined in liter graduated cylinders every two hours, and the return sludge rate was so controlled that the concentration of suspended solids in the return sludge did not exceed the concentration of sludge observed in the settling test after 30 min. Waste activated sludge rates were controlled to the extent possible with the facilities available, so that the suspended solids would not exceed 1,500 p.p.m. and the 30-min. settling test reading would not exceed 300.

Period B represents four months wherein digested sludge was added continuously to the sludge treatment aeration tanks, and the interchange with the activated sludge in these tanks and the activated sludge in the aeration tanks was made at a low rate for 24 hours on alternate days. On days when no interchange was being made the sludge in the sludge treatment tank was circulated from the effluent end to the influent end of the tanks.

During the four months indicated as Period C the process was modified so that digested sludge was added only on days when no interchange was being made and simultaneously the sludge in the sludge treatment aeration tanks was circulated from the effluent end to influent end of the tanks. The interchange was made on alternate days at a low rate over a period of 24 hours. This operation was used in preference to that of Period B for purposes of simplification of operating procedure.

Thus three periods are presented: Period A—immediately prior to the use of the process; Period B—continuous addition of digested sludge and low rate of interchange on alternate days; and Period C—alternate day addition of digested sludge and interchange on alternate days.

## Plant Loading

Table 1 and Figure 2 indicate the raw sewage population equivalent-duration curves for the three periods. In order to better evaluate these curves, consideration should be given to the aeration tank capacities. Using conventional activated sludge plant design data, a plant employing a 6-hr. aeration period and 20 per cent return activated sludge provides an aeration tank capacity of 4 cu. ft. per capita. On this basis the total aeration tank design capacity is 195,300 population equivalent on a raw sewage basis. The population equivalent-duration curves represent the per cent of the time the daily average raw sewage population equivalent exceeded the indicated values. Thus the raw sewage population equivalent was above the 200,000 (design) level 69.1 per cent of the

V.18
1946

**TABLE I.—Duration of Various Population Equivalent Loadings**

| Population Equivalent | Per Cent of Time Exceeded | | |
|---|---|---|---|
| | Period A | Period B | Period C |
| 100,000 | 100 | 100 | 100 |
| 150,000 | 87.7 | 92.1 | 95.0 |
| 200,000 | 69.1 | 84.0 | 85.5 |
| 250,000 | 37.4 | 63.0 | 67.5 |
| 300,000 | 7.3 | 30.2 | 36.8 |
| 350,000 | 1.6 | 7.6 | 17.1 |
| 400,000 | 0.0 | 0.9 | 3.4 |

time during Period A, 84.0 per cent of the time during Period B and 85.5 per cent of the time during Period C. The plant load was above 300,000 population equivalent, or 150 per cent design capacity for 7.3 per cent of the time during Period A, 30.2 per cent of the time during Period B and 36.8 per cent of the time during Period C. Note that during Periods B and C the load exceeded 400,000 population equivalent, or twice the conventional design capacity for the activated sludge portion of the plant.

Thus the plant load during the three periods was considerably above conventional design and the load was lightest during Period A and heaviest during Period C. The average values for the raw sewage population equivalent for the Periods A, B and C were 224,000, 263,000, and 274,000, respectively.

## Effect on Sludge Index

With this picture of the nature of the plant loading, refer to Table II and Figure 3 which represent the sludge index of the aeration tank activated sludge during the three periods. The sludge index exceeded 200 during Period A for 75.4 per cent of the time, during Period B but 1.7 per cent of the time and did not exceed that value during Period C. Note that the sludge index was above 150 during Period A for 92.7 per cent of the time, while during Periods B and C the duration this value was exceeded was but 12.8 and 4.4 per cent, respectively.

At no time during Periods B and C was it necessary to by-pass primary

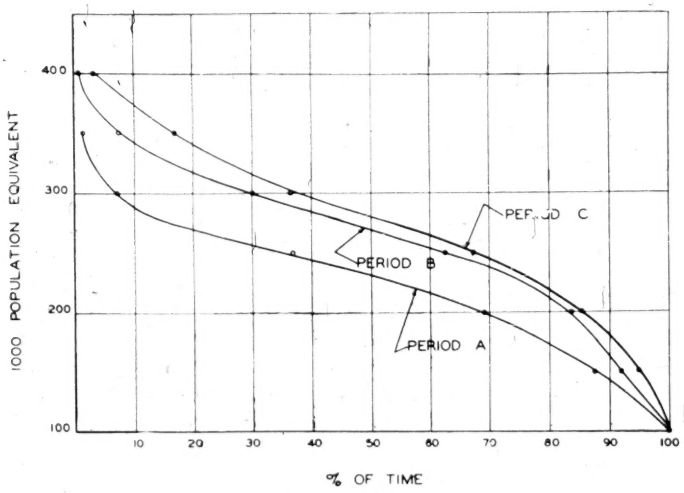


FIGURE 2.—Raw sewage population equivalent loading—duration curves for the three periods studied.

**TABLE II.—Per Cent of Time Sludge Index Exceeded Indicated Values**

| Sludge Index | Per Cent of Time Exceeded | | |
|---|---|---|---|
| | Period A | Period B | Period C |
| 50 | 0 | 100 | 100 |
| 100 | 100 | 77.8 | 78.3 |
| 150 | 92.7 | 12.8 | 4.4 |
| 200 | 75.4 | 1.7 | 0 |
| 250 | 50.9 | 0 | |
| 300 | 23.6 | | |
| 350 | 15.4 | | |
| 400 | 10.9 | | |
| 450 | 8.2 | | |
| 500 | 5.5 | | |

settling tank effluent. As previously noted during Period A, the sludge index exceeded the 350 value 15.4 per cent of the time, and during part of this time by-passing of primary settling tank effluent was necessary in order to minimize loss of sludge from the final settling tanks. The average values of the sludge index for Periods A, B and C were 252, 120 and 118, respectively. It is obvious that the higher sludge density during Periods B and C should result in less loss of solids in the final settling tank and therefore should result in higher plant efficiency.

## Effect on Plant Efficiency

Table III and Figure 4 indicate the overall removal of suspended solids effected by the treatment process during the three periods. These also are duration data and express the per cent of the time the daily average removal of suspended solids was above the values indicated. The values indicated under Period A are not corrected for by-passed primary effluent but repre-

**TABLE III.—Duration of Various Percentages of Overall Removal of Suspended Solids**

| Per Cent Overall Removal of Suspended Solids | Per Cent of Time Exceeded | | |
|---|---|---|---|
| | Period A | Period B | Period C |
| 70 | 100 | | |
| 75 | 98.3 | | |
| 80 | 97.5 | | |
| 85 | 90.7 | 100 | 100 |
| 90 | 69.5 | 99.2 | 96.7 |
| 95 | 24.6 | 70.0 | 48.3 |

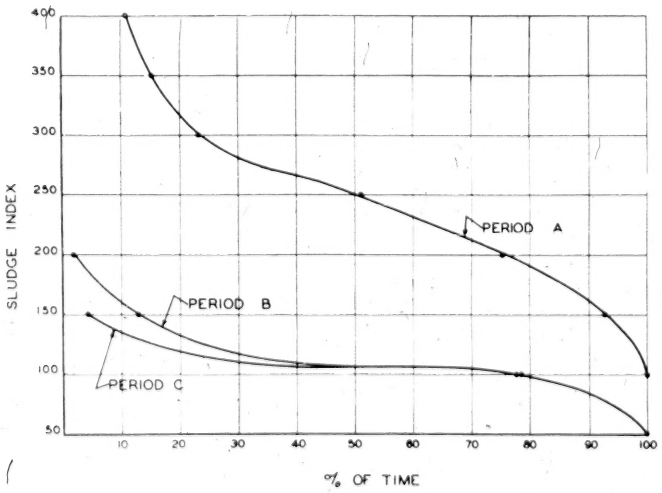


**FIGURE 3.—Activated sludge index duration curves during the three periods studied.**

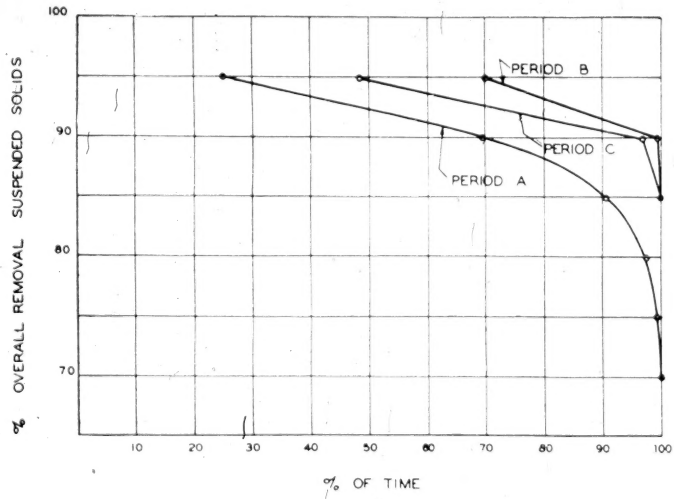


FIGURE 4.—Overall removal of suspended solids—duration curves for the three periods studied.

sent the character of the final effluent as compared to the raw sewage. The removal of suspended solids was above the 95 per cent value 24.6 per cent of the time during Period A, 70.0 per cent of the time during Period B and 48.3 per cent of the time during Period C.

The removal of suspended solids was above 90 per cent for 69.5 per cent of the time during Period A, 99.2 per cent of the time during Period B and 96.7 per cent of the time during Period C. The average removal of suspended solids during Periods A, B and C were 91.5 95.4 and 94.6 per cent, respectively.

Likewise Table IV and Figure 5 represent the percentage overall removal of B.O.D. by referring the final effluent B.O.D. to the raw sewage B.O.D. Here again the data are similar although the differences between Periods B and C and Period A are more pronounced. Note that removals above 95 per cent were effected during Period A but 19.5 per cent of the time, while during Periods B and C the duration of this efficiency was 68 and 42 per cent, respectively. Furthermore, while B.O.D. removal efficiency during Periods B and C exceeded 90 per cent for 99.2 and 92.4 per cent of the time, respectively, this value was exceeded but 59.3 per cent of the time during Period A. The average removal of B.O.D. during the Periods A, B and C were 89.9, 95.0 and 94.0 per cent, respectively.

TABLE IV. Duration of Various Percentages of Overall Removal of B.O.D.

| Per Cent Overall Removal of B.O.D. | Per Cent of Time Exceeded | | |
|---|---|---|---|
| | Period A | Period B | Period C |
| 65 | 100 | — | — |
| 70 | 99.2 | — | — |
| 75 | 95.8 | — | — |
| 80 | 91.5 | — | — |
| 85 | 82.2 | 100 | 100 |
| 90 | 59.3 | 99.2 | 92.4 |
| 95 | 19.5 | 57.2 | 42.4 |

It is apparent from these data that efficiency of the activated sludge proc-

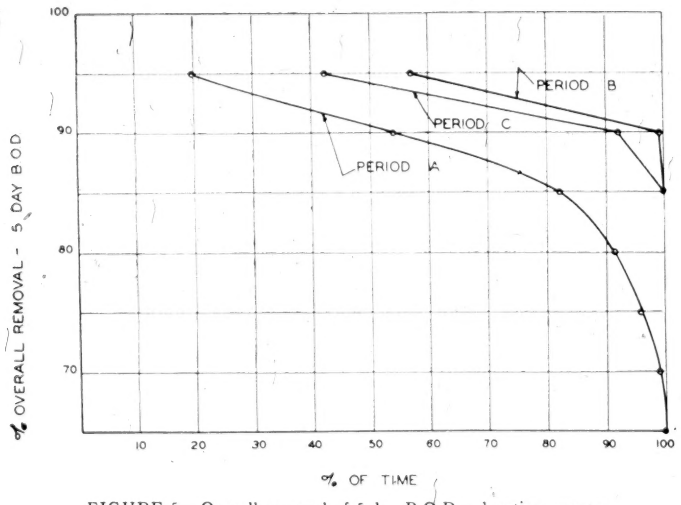


FIGURE 5.—Overall removal of 5-day B.O.D.—duration curves for the three periods studied.

ess was improved considerably during Periods B and C, when the digested sludge addition and interchange procedure were in use, compared to results during Period A previous to the use of the process. In order to evaluate further these data, a comparison of the operating characteristics, air requirements and load must be examined. Toward this end is presented Figure 6

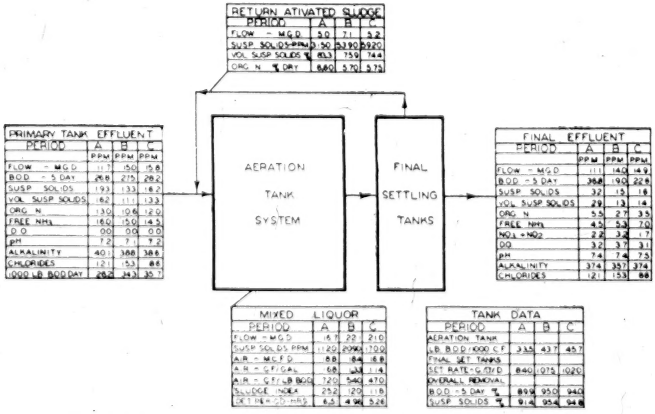
RETURN ATIVATED SLUDGE
PERIOD A B C
FLOW - MGD 3.0 7.1 3.2
SUSP. SOLIDS PPM 3.50 5390 2920
VOL. SUSP SOLIDS % 853 759 744
ORG. N % DRY 8.80 5.70 5.75
PRIMARY TANK EFFLUENT
PERIOD A B C
PPM PPM PPM
FLOW - MGD 11.3 15.0 15.8
BOD - 5 DAY 268 275 282
SUSP. SOLIDS 193 133 162
VOL. SUSP. SOLIDS 182 111 133
ORG. N 13.0 10.6 12.0
FREE NH3 16.0 15.0 14.5
DO 0.0 0.0 0.0
pH 7.2 7.1 7.2
ALKALINITY 401 388 386
CHLORIDES 121 53 88
1000 LB BOD/DAY 252 243 30.7
AERATION TANK SYSTEM
FINAL SETTLING TANKS
FINAL EFFLUENT
PERIOD A B C
PPM PPM PPM
FLOW - MGD 11.1 14.0 14.9
BOD - 5 DAY 358 190 224
SUSP. SOLIDS 32 15 18
VOL. SUSP. SOLIDS 29 13 14
ORG. N 5.5 2.7 3.5
FREE NH3 4.5 5.3 7.0
NO2 + NO3 2.2 3.2 1.7
DO 3.2 3.7 3.1
pH 7.4 7.4 7.3
ALKALINITY 374 357 374
CHLORIDES 121 153 88
MIXED LIQUOR
PERIOD A B C
FLOW - MGD 15.7 22.1 21.0
SUSP SOLIDS PPM 1129 2090 1709
AIR - MCFD 88 84 68
AIR - CF/GAL 6.8 3.8 4.
AIR - CF/LB BOD 320 540 470
SLUDGE INDEX 252 129 118
DETENTION HRS 6.5 4.95 5.26
TANK DATA
PERIOD A B C
AERATION TANK
LB BOD/1000 C.F. 33.5 43.7 45.7
FINAL SET. TANKS
SET RATE - G/D/S.F. 840 975 1020
OVERALL REMOVAL
BOD - 5 DAY % 89% 95.0 94.0
SUSP SOLIDS % 91.4 95.4 94.8

FIGURE 6.—Average data for activated sludge system during the three periods studied.

setting forth the average conditions in the activated sludge portion of the plant during each period.

### Effect on Activated Sludge Plant

The data presented in Figure 6 indicate that the load on the aeration tank system as expressed in pounds of primary tank effluent B.O.D. per day was appreciably higher during Periods B and C than during Period A, the values being 34,300 and 35,700 during Periods B and C, respectively, and but 26,200 during Period A. When expressed in terms of pounds of B.O.D. per day per 1,000 cu. ft. of aeration tank volume, the loadings for the Periods A, B and C were 33.5, 43.7 and 45.7, respectively. In a conventionally designed activated sludge plant employing primary sedimentation the normal loading of primary tank effluent B.O.D. is approximately 28 lb. per 1,000 cu. ft. of aeration tank capacity per day.

Approximately the same volume of air was used during Periods A and B—18.8 and 18.4 million c.f.d., respectively—with a reduction in air used during Period C to 16.8 million c.f.d. This resulted in the use of 1.68 cu. ft. of air per gallon of sewage for the "bulking" Period A, while during Periods B and C the amounts of air were reduced to 1.33 and 1.14 cu. ft. per gallon, respectively. Combining air used and load applied, the values of cubic feet of air per pound of B.O.D. for the Periods A, B and C were 720, 540 and 470, respectively. These values are total air to the system and include the air to the aeration tanks and also the air to the sludge treatment aeration tanks.

Note also that the aeration times for the three periods were 6.51 hr. for Period A, 4.96 hr. for Period B and 5.27 hr. for Period C. Thus during Period A we have the lightest load, the greatest quantity of air per unit of volume and B.O.D., and the longest aeration period. Despite these advantages the process was less efficient and the sludge bulked for practically the entire 4-month period.

Note that during Period A the mixed liquor solids were kept at a much lower value than during Periods B and C and that, while the settling rates in the final settling tanks for this material were also lower, the suspended solids in the effluent were practically double that during the last two periods.

Note also that the effect of adding digested sludge to the system during Periods B and C resulted not only in a reduction in the index of the activated sludge but also in a reduction in volatile matter content, with the accompanying reduction in organic nitrogen content, the latter reduction being from 6.6 per cent to about 5.7 per cent on a dry solids basis.

### Effect on Primary Settling Tanks

In an activated sludge plant employing primary sedimentation, wherein the waste activated sludge is added to the influent to the primary settling tanks, considerable difficulty may be encountered during periods when the activated sludge bulks. During such periods sharp increases in the sludge index are observed, and these necessitate rapid wasting of activated sludge solids in order to maintain an aeration tank effluent that can be settled in the final settling tanks. The large quantities of low density solids wasted to the primary settling tank cause rapid increases in the sludge blanket at the bottom of these tanks and this, in turn, causes loss of suspended solids from these tanks. Consequently, there is an increase in the amount of solids required to be wasted from the activated sludge system. Thus a vicious cycle is established which can ultimately cause the settling process to get out of control and which will finally result in the loss of large quantities of activated sludge in the final effluent.

In Figure 7 are presented the flow diagram and data showing the condi-

tion of the primary settling tanks for the three periods studied. Noteworthy is the effect on the activated sludge wasted from the system. During Periods B and C the concentration of the waste activated sludge is increased materially over Period A, but in addition the volume of waste activated sludge is also increased. This is due to the need for wasting not only the activated sludge produced from the removal of materials from the primary tank effluent treated but also the digested sludge that is converted to activated sludge. Thus during Period B about 56 per cent greater volume of wasted activated sludge was required than during Period A. It should be pointed out, however, that due to the relatively narrow limits of sludge index range and the low rate of change of sludge index during Period B, at no time were the facilities for wasting activated sludge overtaxed as they were many times during Period A.

The same effect is also noted on the primary settling tank sludge. Here, however, the increase in volume during Periods B and C is 14.0 per cent and 20.2 per cent, respectively, over Period A.

The displacement period in the primary settling tanks was slightly less during Period B than during Period A, but the removal of suspended solids during the former period was 59.2 per cent against 50.3 per cent during the latter period. This is undoubtedly due to the higher density of waste activated sludge during Period B. These values of removal of suspended solids do not include the waste activated sludge, but are based on the raw sewage and primary settling tank effluent suspended solids.

### Effect on Primary Digestion Tanks

The effect of the process on the primary digestion tanks is of much interest since it might appear that the recirculation of the sludge through the aeration tanks and digesters could result in more gas production and greater reductions of organic solids. The data presented in Figure 8 for the three periods studied disclose that these expectations do not occur. The effect on the primary digesters is reflected in a de-

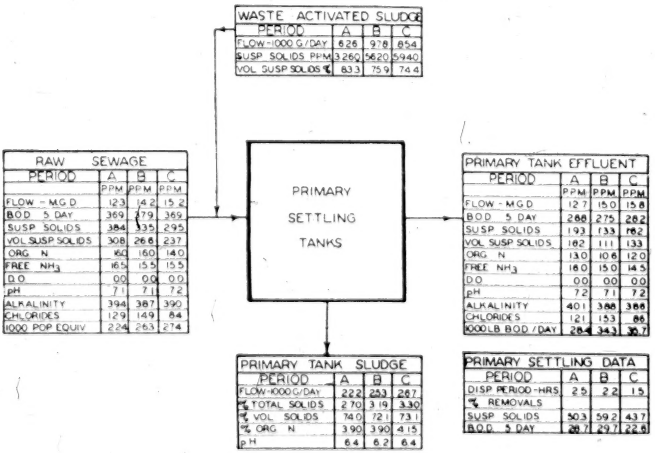
WASTE ACTIVATED SLUDGE
PERIOD A B C
FLOW-1000 G/DAY 626 978 854
SUSP. SOLIDS PPM 3260 5620 5940
VOL. SUSP SOLIDS % 83.3 75.9 74.4
RAW SEWAGE
PERIOD A B C
PPM PPM PPM
FLOW - M.G.D. 123 142 152
B.O.D. 5 DAY 369 379 369
SUSP. SOLIDS 384 335 295
VOL. SUSP SOLIDS 308 268 237
ORG. N 102 160 140
FREE NH3 165 155 155
D.O. 00 00 00
pH 71 71 72
ALKALINITY 394 387 390
CHLORIDES 129 149 84
1000 POP. EQUIV 224 263 274
PRIMARY SETTLING TANKS
PRIMARY TANK EFFLUENT
PERIOD A B C
PPM PPM PPM
FLOW - M.G.D. 127 150 158
B.O.D. 5 DAY 288 275 282
SUSP. SOLIDS 193 133 162
VOL. SUSP. SOLIDS 162 111 133
ORG. N 130 106 120
FREE NH3 180 150 145
D.O. 00 00 00
pH 72 71 72
ALKALINITY 401 388 388
CHLORIDES 121 153 86
1000 LB. BOD / DAY 284 343 307
PRIMARY TANK SLUDGE
PERIOD A B C
FLOW-1000 G/DAY 222 253 287
% TOTAL SOLIDS 270 319 330
% VOL. SOLIDS 740 721 731
% ORG. N 390 390 415
pH 64 62 64
PRIMARY SETTLING DATA
PERIOD A B C
DISP. PERIOD-HRS. 25 22 15
% REMOVALS
SUSP. SOLIDS 503 592 437
B.O.D. 5 DAY 287 297 226

**FIGURE 7.—Average data for the primary settling tanks during the three periods studied.**

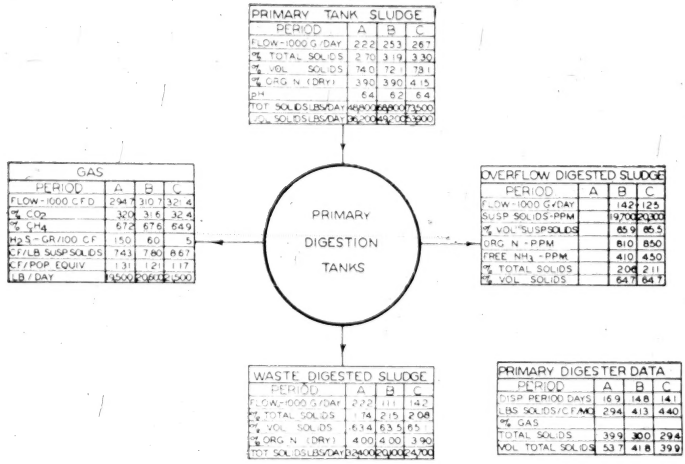
PRIMARY TANK SLUDGE
PERIOD A B C
FLOW-1000 G/DAY 222 253 267
% TOTAL SOLIDS 2.70 3.19 3.30
% VOL. SOLIDS 74.0 72. 73.1
% ORG. N. (DRY) 3.90 3.90 4.15
pH 6.4 6.2 6.4
TOT. SOLIDS-LBS/DAY 49,900 68,000 73,500
VOL. SOLIDS-LBS/DAY 36,900 49,000 53,900
GAS
PERIOD A B C
FLOW-1000 C.F.D. 294.7 310.7 321.4
% CO2 32.0 31.6 32.4
% CH4 67.2 67.6 64.9
H2S - GR/100 C.F. 1.50 .60 .5
C.F./LB SUSP.SOLIDS 7.43 7.80 8.67
C.F./POP. EQUIV. 1.31 1.21 1.17
LB./DAY 14,500 20,600 21,900
PRIMARY DIGESTION TANKS
OVERFLOW DIGESTED SLUDGE
PERIOD A B C
FLOW-1000 G/DAY 142 125
SUSP. SOLIDS-PPM 19,700 20,300
% VOL. SUSP. SOLIDS 65.9 65.5
ORG. N. - PPM 810 850
FREE NH3 - PPM 410 450
% TOTAL SOLIDS 2.06 2.11
% VOL. SOLIDS 64.7 64.7
WASTE DIGESTED SLUDGE
PERIOD A B C
FLOW-1000 G/DAY 222 111 142
% TOTAL SOLIDS 1.74 2.15 2.08
% VOL. SOLIDS 63.4 63.5 65.
% ORG. N. (DRY) 4.00 4.00 3.90
TOT. SOL. LBS/DAY 34,600 39,000 44,700
PRIMARY DIGESTER DATA
PERIOD A B C
DISP. PERIOD DAYS 16.9 14.8 14.1
LBS. SOLIDS/C.F.M.D. 2.94 4.13 4.40
% GAS
TOTAL SOLIDS 39.9 30.0 29.4
VOL. TOTAL SOLIDS 53.7 41.8 39.9

FIGURE 8.—Average data for the primary digestion tanks during the three periods studied.

crease in volume of the waste digested sludge. This is brought about by an increase in total solids concentration of the digested sludge wasted and also by the wet combustion of some of the solids in the sludge treatment aeration tank.

An inspection of the gas production data indicates that while more gas was produced per pound of suspended solids in the raw sewage during Periods B and C than during Period A, the reverse is true when the gas volume is expressed per unit of population equivalent. In addition, when the weight of the gas is expressed as per cent of the total and volatile solids added to the primary digesters, the results indicate that no appreciably greater quantity of gas is produced during Periods B and C than during Period A.

The operation of the primary digesters is such as to maintain homogeneous conditions in the digester contents. This is accomplished by the gas lift effect and also by circulation between the bottom and top of the tanks.

It should be observed that during Periods B and C large quantities of digester overflow containing about 20,000 p.p.m. suspended solids were added to the aeration system. This was done without any deleterious effect on the system; instead, the effect was to improve its operation.

Thus it may be stated that the greatest effect of the process on the digestion tanks is to eliminate completely the problem created by digester overflow or so-called "supernatant liquor." This material may be added to the activated sludge system in the manner herein outlined without producing the serious problems created by it in many sewage treatment plants.

## Sludge Treatment Aeration Tank Operation

The sludge treatment aeration tank operation was carried out with continuous addition of digested sludge during Period B and addition of digested sludge on alternate days during Period C. The interchange of conditioned sludge and activated sludge

in the aeration tanks was made on alternate days. Thus during Period B digested sludge was added during the period of interchange, and during Period C digested sludge was added on one day and on the following day the interchange was made and no digested sludge was added during that day. In both periods sludge was circulated from the effluent end of the sludge treatment aeration tank to the influent end when no interchange was being made.

Figure 9 indicates the flow diagram in the activated sludge portion of the plant. The data presented in this figure are not entirely self-explanatory, since, while all data represent averages of daily data, the process is discontinuous. Thus during Period C digester overflow was added on alternate days at a rate of 250,000 g.p.d. This value expressed on a daily basis as recorded in the table is 125,000 g.p.d. Likewise the sludge treatment tank composites were taken before and after the interchange on alternate days. Thus while the flow diagram arrows represent the conditions during the interchange procedure, only that portion of the tabular data other than the above named can be thought of as actual daily average conditions.

In order to determine the amount of digested sludge required to be added to the activated sludge system, three ratios of digested sludge suspended solids to primary settling tank effluent suspended solids were used: namely, 2 to 1, 1 to 1 and 0.5 to 1. The three ratios resulted in activated sludge with a sludge index generally under 100 for the 2:1 ratio, between 100 to 150 for the 1:1 ratio and between 150 and 200 for the 0.5:1 ratio. The 2:1 ratio operation resulted in excellent sludge index control since the low sludge index permitted the maintenance of the greatest quantity of activated sludge in the system and, therefore, resulted in the lowest rate of change of sludge index. This ratio of digested sludge suspended solids to primary settling tank effluent suspended solids was not considered the most satisfactory from a practical viewpoint, primarily because it occasionally overtaxed the existing facilities for pumping primary settling tank sludge to the digestion tanks. The ratio of 0.5:1, which resulted in sludge indices between 150 and 200, produced the

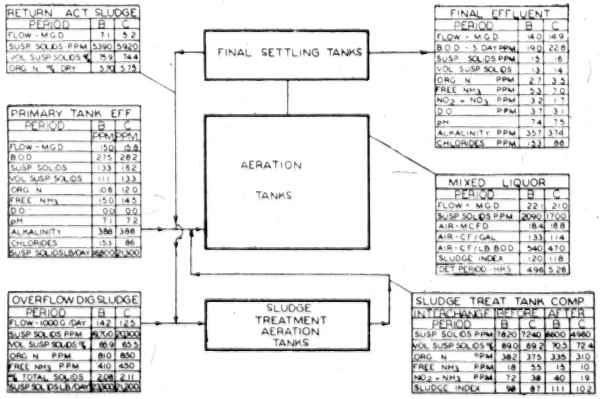
RETURN ACT SLUDGE
PERIOD B C
FLOW - MGD 7.1 5.2
SUSP SOLIDS PPM 5390 5920
VOL SUSP SOLIDS % 75.9 74.4
ORG N % DRY 5.75 5.75
PRIMARY TANK EFF
PERIOD B C
FLOW - MGD 15.0 15.8
BOD 215 282
SUSP SOLIDS 133 162
VOL SUSP SOLIDS 111 133
ORG N 0.8 12.0
FREE NH3 15.0 14.5
D O 0.0 0.0
PH 7.1 7.2
ALKALINITY 388 388
CHLORIDES 153 86
SUSP SOLIDS/DAY 16000 21,000
OVERFLOW DIG SLUDGE
PERIOD B C
FLOW - 1000 G/DAY 142 125
SUSP SOLIDS PPM 30,700 32,000
VOL SUSP SOLIDS % 88.9 85.5
ORG N PPM 810 850
FREE NH3 PPM 410 430
% TOTAL SOLIDS 2.05 2.11
SUSP SOL DISP/DAY 350,000
FINAL SETTLING TANKS
AERATION TANKS
SLUDGE TREATMENT AERATION TANKS
FINAL EFFLUENT
PERIOD B C
FLOW - MGD 14.0 14.9
B O D - 5 DAY PPM 19.0 22.6
SUSP SOLIDS PPM 13 16
VOL SUSP SOLIDS 13 14
ORG N PPM 2.7 3.2
FREE NH3 PPM 2.3 2.0
NO2 + NO3 PPM 3.2 1.7
D O PPM 3.7 3.1
PH 7.4 7.5
ALKALINITY PPM 357 374
CHLORIDES PPM 153 86
MIXED LIQUOR
PERIOD B C
SETTLING 22 21.0
SUSP SOLIDS PPM 2090 1700
AIR - MCFD 184 188
AIR - CF/GAL 1.33 1.14
AIR - CF/LB BOD 540 470
SLUDGE INDEX 120 118
SET PERIOD - HRS 4.96 5.28
SLUDGE TREAT TANK COMP
INTERCHANGE BEFORE AFTER
PERIOD B C B C
SUSP SOLIDS PPM 7820 7240 8600 8980
VOL SUSP SOLIDS % 89.0 89.2 90.3 72.4
ORG N PPM 382 375 335 310
FREE NH3 PPM 18 55 15 10
NO2 + NO3 PPM 72 38 40 19
SLUDGE INDEX 98 87 111 102

**FIGURE 9.—Average operating data during Periods B and C for the activated sludge portion of the plant.**

most sparkling and clarified final effluent, but this operation effected a lower quantity of solids in the activated sludge system and necessarily brought about greater rates of change in sludge index.

Thus the ratios of 2:1 and 0.5:1 were found to be not entirely satisfactory for the existing plant facilities and operating conditions, and the operation of a 1:1 ratio was used as more satisfactory. This ratio precluded the need for handling an unduly large amount of primary settling tank sludge and at the same time maintained sufficient activated sludge in the system to afford a buffer against rapid rates of change of sludge index. The Periods B and C in Figure 9 represent such operation.

As previously cited the digested sludge was added to the sludge treatment tank as digester overflow. Note that during both periods the suspended solids were in the order of 20,000 p.p.m. and the free ammonia content above 400 p.p.m. in this material. Activated sludge was mixed with the digester overflow and the mixture aerated in the sludge treatment aeration tank for a sufficient time to convert the digested sludge to activated sludge. The interchange of this sludge and the aeration tank activated sludge was performed on alternate days.

The sludge treatment tank analyses were made on a composite of grab samples taken at 27 points in the sludge treatment aeration tanks, immediately before and after the interchange. Much of the ammonia nitrogen was converted to nitrate and nitrite nitrogen, the average values for the composite samples taken before the interchange being 72 p.p.m. for Period B and 38 p.p.m. for Period C. The nitrate and nitrite content decreased to 40 and 19 p.p.m., respectively, for the two periods after the interchange. The amount of this nitrate plus nitrite nitrogen loss is that quantity which was added to the aeration tanks during the interchange period.

In the activated sludge system as operated during Periods B and C when no interchange was being made, the aeration tanks were operated as conventional aeration tanks. During such operation the B.O.D. loading of the aeration tanks was very high and the air supply comparatively low. During Periods B and C, on days when no interchange was being made, the B.O.D. loadings were 58.3 and 60.9 lb. per 1,000 cu. ft. of aeration tank capacity per day, respectively, and the air applied in these tanks but 360 and 310 cu. ft. per pound B.O.D., respectively. These values are in the order of one-half that normally considered necessary for good operation. In addition, these are average values, and plant loadings were above average values for 57 per cent of the time during Period B and 54 per cent of the time during Period C.

Under these conditions of operation the sludge index generally increases, and on days of interchange the sludge index decreases. The operation is so regulated that the decrease in sludge index on days of sludge interchange is at least equal to the increase in sludge index on days when no such interchange is being made. It can be verified from the data here presented that the sludge index obtained by mixing two sludges is equivalent to the weighted average of the sludge indices of the sludges mixed. Thus is established a control whereby it is possible to obtain any desired sludge index within the limits of the characteristics of the available sludges, whether these sludges be digested or activated sludges.

## Control

In order to test further the efficacy of the process and to observe whether a change in the character of the sewage or in the method of operation were

responsible for the favorable results observed, the addition of digested sludge was stopped during two 10-day intervals, one prior to Period B and one after Period B.

The first test was started when the sludge index was 81 and after 10 days the sludge index was 353. The second test was started when the sludge index was 110 and after 10 days the sludge index was 283.

On another occasion immediately preceding Period C the aeration tanks were drained for cleaning of the air diffusers. When the aeration tanks were again placed in operation no digested sludge was added for 6 days. At the end of the 6th day the sludge index was 261.

It appears from these control observations that the tendency toward bulking of the activated sludge persisted before and after Period B and immediately preceding Period C. These data seem sufficiently conclusive to support the belief that the digested sludge and the process of its application here presented result in a means of control of the sludge index of activated sludge.

## Summary and Conclusions

Three periods of operation are described, one before the use of the process herein presented and two during the use of the process.

From the data assembled the following conclusions may be drawn:

1. That the process affords a means of control of the sludge index of activated sludge.

2. That the process reduces the effect of shock loads on the activated sludge to the end that the period of loss of clarification is minimized.

3. That nitrate nitrogen is added to the influent to the activated sludge tanks, thus affording an immediate oxygen reserve which supplements the dissolved oxygen supply in that part of the aeration tank where the oxygen utilization rate is a maximum.

4. That the use of the process requires somewhat greater pumping capacity for waste activated sludge and primary settling tank sludge than is required in the conventional activated sludge process.

5. That the process requires no more air than the conventional process.

6. That the process is capable of continuous high degree purification.

7. That the process increases materially the load capacity of an activated sludge plant.

8. That the process completely eliminates the so-called "supernatant problem."

9. That the process transforms conventional activated sludge treatment from a sensitive process, incapable of continuous high degree purification when subjected to shock loads of dissolved organic material, to a rugged process with capacity for effectively purifying such shock loads.

# MODERNIZATION OF THE B.O.D. TEST FOR DETERMINING THE EFFICACY OF SEWAGE TREATMENT PROCESSES

By Clair N. Sawyer * and Leland Bradney

*Special Investigator, South Dakota State Board of Health, and Operating Chemist, Sioux Falls, S. D. Sewage Treatment Plant, Respectively*

The effectiveness of sewage treatment facilities is generally expressed in terms of removals of suspended solids and biochemical oxygen demand. Although the criterion which determines whether a given plant is a success or a failure depends upon whether the effluent can be added to the receiving body of water without the development of nuisance conditions at all times, the superintendent of a sewage works finds it desirable to have a day-by-day record of what his plant is accomplishing in regard to removal of these factors.

The measurement of a plant's effectiveness in removing suspended solids poses no particularly difficult problems as the problem lends itself to gravimetric analysis, involving well standardized procedures. On the other hand, the measurement of a plant's effectiveness in removing or stabilizing those substances responsible for B.O.D. is quite another matter. This difficulty was first shown by Theriault (1) to be due to a nitrogenous oxygen demand, thus indicating very poor percentage removals of B.O.D. It is the purpose of this paper to re-emphasize this serious shortcoming of present methods of determining B.O.D. removals and to present a method of overcoming the disadvantage.

## Present Interpretation of B.O.D. Results

The development of the present-day B.O.D. test, involving the dilution technique, has been largely the result of studies carried on by British and American investigators. In this country Hommon and Theriault, working for the USPHS, have been most instrumental in developing the test to its present stage. Their data obtained upon polluted waters of various degrees have shown the nature of the biochemical oxygen demand of a water polluted with human wastes to be somewhat like that shown in Figure 1.

Their studies have shown the oxygen demand during the first ten days to be largely a result of biological stabilization of carbonaceous material. After the carbonaceous oxidation is nearly complete, conditions allow the development of a nitrifying flora which oxidizes the ammonia to nitrites and the nitrites to nitrates. This causes an increased oxygen demand and results in a second inflection in the B.O.D. curve as shown in Figure 1.

The measurement of B.O.D. loadings on sewage treatment plants is normally done by means of the conventional 5-day test. Consequently, the course of oxidation does not proceed into the nitrification stage and only carbonaceous B.O.D. is measured. This may be used as 5-day B.O.D. or it may be converted to total demand but, in any case, it represents only carbonaceous B.O.D. loadings.

Sewage treatment plants are designed to accomplish in a few hours a degree of treatment that would normally require several days under natural conditions. As a result of this accelerated rate, the treatment is often

* Present address: Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Cambridge 39, Mass.

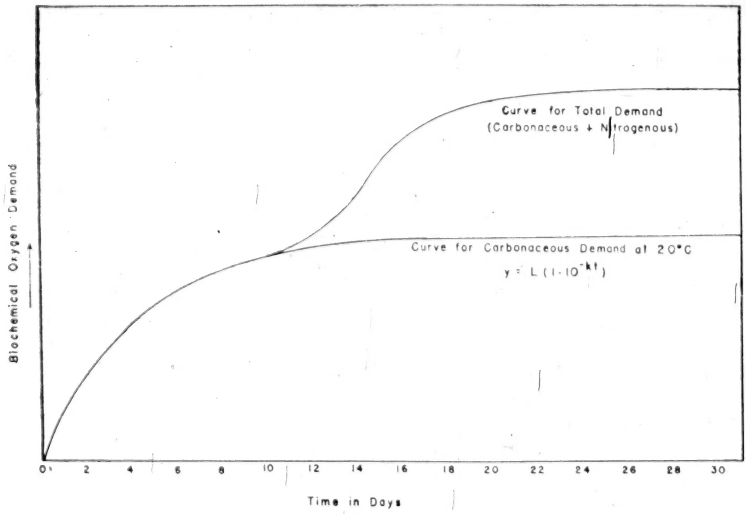


FIGURE 1.—The biochemical oxygen demand curve—showing the influence of nitrogenous oxidation in altering the total demand.

carried into the nitrification stage and when B.O.D. tests are run on the final effluent a considerable nitrogenous B.O.D. will superimpose itself upon the small residual carbonaceous B.O.D. which exists. Such B.O.D. values, of course, are misleading and do not allow development of a true picture of what has been accomplished in the line of carbonaceous B.O.D. stabilization, *i.e.* calculation of per cent removal of imposed load. In fact, it is theoretically possible for plant effluents which are in the so-called "incipient nitrification stage" to exhibit greater 5-day B.O.D. values than those shown by the untreated sewages. This factor has tended to place in a rather unfavorable light those operators who strived to get a reasonable degree of nitrification in their plant effluents. To overcome this disadvantage, operators who have been fully aware of the nature of the biochemical oxygen demand curve have tried to hold nitrification to a minimum in order to produce a more satisfactory B.O.D. removal record. The "pros and cons" of this practice were discussed in an editorial by Dr. F. W. Mohlman (2) in 1938.

Another indication that sewage works men have been concerned with the correlation between high effluent B.O.D. and nitrification is centered in the arguments concerning the relative merits of bicarbonate and phosphate dilution waters. One of the major arguments advanced in favor of the phosphate dilution water was that, because of its lower pH, it was less conducive to the development of nitrification in the B.O.D. bottle. Phosphate dilution water has displaced bicarbonate water at some treatment plants on this argument alone. These factors all add up to indicate that sewage works men are not interested in measuring nitrogenous B.O.D. if they can avoid it. After all, why should we allow such interference, if we are concerned with the measurement of residual carbonaceous B.O.D. in plant effluents,

and the determination of plant efficiencies therefrom?

## B.O.D. Problems at Sioux Falls

The sewage treatment plant at Sioux Falls treats both industrial (mainly packinghouse waste) and domestic wastes. The former are given two stages of filter treatment before being admitted to the activated sludge units. The domestic sewage can be treated with the industrial wastes on the secondary filters or can be sent directly to the aeration tanks where it mixes with the twice-filtered industrial sewage for final treatment.

A study of B.O.D. removals accomplished in the aeration unit showed tremendous day-to-day variations, with negative removals occurring quite frequently. Although there was some correlation between poor removals and suspended solids (caused by floating sludge) in the final effluent, the correlation was not perfect and indicated that the B.O.D. data might be at fault. It had been the custom to determine B.O.D. by setting up one dilution on each sample. Instructions were issued, therefore, to use two dilutions on the final effluent; usually 10 and 5 per cent mixtures were set up thereafter.

Early results obtained with two dilutions of the final effluent gave in most cases considerably higher B.O.D. values on the low dilutions, or 10 per cent mixtures, as shown in Table I. These data indicated that some toxic factor might be present in the dilution water. Consequently, a study was made of dilution waters prepared from distilled waters obtained from four other sources. All gave the same differences as the original water.

The next step was to check the quality of the dilution water by setting up different dilutions of other samples, such as settled domestic sewage, which normally yield rather close B.O.D. values in different dilutions. The results of this study are shown in Table II and indicate that no toxic factor

**TABLE I.—Showing Variation in B.O.D. of Final Effluent as Influenced by Dilution**

| Date | 5-Day B.O.D. (p.p.m.) | |
|---|---|---|
| | Low Dilution (10%) | High Dilution (5%) |
| 1-27-45 | 54 | 42 |
| 28 | 27 | 17 |
| 29 | 69 | 46 |
| 30 | 65 | 53 |
| 31 | 68 | 50 |
| 2-1-45 | 38 | 23 |
| 2 | 47 | 29 |
| 3 | 63 | 26 |
| 4 | 18 | 9 |
| 5 | 63 | 25 |
| Ave. | 51 | 32 |

was present, since the different dilutions checked reasonably well and there was no tendency for the low dilution to run high. It was concluded therefrom that the difficulty was not in the dilution water but, rather, in the nature of the final effluent samples. A study of the B.O.D. and nitrification data showed that the greatest discrepancies in B.O.D. values on different dilutions were obtained during periods when nitrification was well established. A check on the amount of nitrification which was occurring in the B.O.D. bottle during the 5-day test of final

**TABLE II.—Showing B.O.D. of Settled Domestic Sewage on Different Dilutions of Samples**

| Date | 5-Day B.O.D. (p.p.m.) | |
|---|---|---|
| | Low Dilution | High Dilution |
| 2-8-45 | 153 | 133 |
| 9 | 100 | 135 |
| 12 | 153 | 147 |
| 13 | 133 | 140 |
| 14 | 107 | 100 |
| 15 | 153 | 146 |
| 16 | 187 | 186 |
| 17 | 190 | 186 |
| 19 | 184 | 180 |
| 20 | 163 | 173 |
| Ave. | 152 | 153 |

effluent showed that a large percentage of the 5-day B.O.D. was due to oxidation of nitrogenous matter.

## Pasteurization Procedure Adopted

In order to eliminate the oxidation of nitrogenous matter in the B.O.D. test and allow the measurement of residual carbonaceous B.O.D., a pasteurization procedure was adopted. This consisted of a flash pasteurization by heating the sample to 80° C. and immediately cooling to 20° C. After cooling, the samples were shaken in stoppered flasks to saturate them with oxygen. A comparison of B.O.D. results obtained upon pasteurized and unpasteurized samples is shown in Table III. It will be noted that reasonable checks were obtained with different dilutions on the pasteurized samples, a good indication that nitrification had been eliminated.

The question naturally arose as to the effect of the pasteurization method upon the determination of ordinary carbonaceous B.O.D. Several samples

**TABLE III. Effect of Flash Pasteurization at 80° C. on B.O.D. of Final Effluent**

| Date | 5-Day B.O.D. (p.p.m.) | | | |
|---|---|---|---|---|
| | Unpasteurized | | Pasteurized | |
| | Low Dilution | High Dilution | Low Dilution | High Dilution |
| 3-24-45 | 124 | 88 | 28 | 28 |
| 25 | 63 | 48 | 18 | 16 |
| 26 | 110 | 44 | 20 | 20 |
| 27 | 126 | 52 | 22 | 20 |
| 28 | 80 | 40 | 34 | 24 |
| 29 | 126 | 72 | 22 | 24 |
| 30 | 124 | 76 | 30 | 32 |

which do not ordinarily exhibit any nitrification during the 5-day test were selected and subjected to pasteurization. The results of the studies are shown in Table IV and indicate that the pasteurization procedure has little effect on the determination of normal carbonaceous B.O.D. It should be

**TABLE IV.—Effect of Flash Pasteurization at 80° C. on B.O.D. of Samples which Showed No Nitrification in the Regular 5-Day Test**

| Sample | 5-Day B.O.D. (p.p.m.) | | | |
|---|---|---|---|---|
| | Unpasteurized | | Pasteurized | |
| | Low Dil. | High Dil. | Low Dil. | High Dil. |
| Domestic Sewage Clarifier Eff. | 126 | 113 | 123 | 113 |
| Domestic Sewage Clarifier Eff. | 133 | 153 | 143 | 153 |
| Domestic Sewage Clarifier Eff. | 133 | 133 | 140 | 133 |
| Ind. Wastes Clarifier Eff. | 475 | 420 | 416 | 453 |
| Prim. Filter Clarifier Eff. | 240 | 243 | 218 | 248 |

stated that the dilution water used was in all cases seeded with settled domestic sewage according to accepted practice.

## Optimum Temperature for Pasteurization

The selection of 80° C. used in the early studies was strictly arbitrary. In order to determine the lowest flash pasteurization temperature which will destroy the nitrifying flora in a sample, studies were made at temperatures ranging from 50° to 80° C., at 5° intervals. The B.O.D. and nitrification data obtained are presented in Table V. These data show that the nitrifying flora readily succumb at a temperature of 55° C. and that higher temperatures, including 80° C., are not detrimental to the determination of residual carbonaceous B.O.D. It does not appear that there is any particular optimum temperature but, to insure a factor of safety, a temperature of 60° C. has been selected as being adequate and most suitable.

In order to determine the effect of pasteurization at 60° C. on the determination of carbonaceous B.O.D., all samples which are normally ana-

**TABLE V.—Effect of Flash Pasteurization Temperature on B.O.D. and Nitrification of Final Effluent**

| Pasteurization Temp. (° C.) | 5-Day B.O.D. (p.p.m.) | | Change in Oxidized-N |
|---|---|---|---|
| | Low Dilution | High Dilution | High Dilution |
| Control | 66 | 36 | +0.38 |
| 50 | 57 | 32 | +0.11 |
| 55 | 24 | 24 | −0.06 |
| 60 | 22 | 22 | −0.09 |
| 65 | 23 | 22 | −0.01 |
| 70 | 22 | 20 | −0.06 |
| 75 | 23 | 24 | −0.06 |
| 80 | 23 | 22 | −0.06 |

lyzed in the Sioux Falls laboratory were subjected to the test. The results are given in Table VI and illustrate, as did the data in Table IV, that pasteurization does not seriously interfere with the regular B.O.D. test as used for measuring carbonaceous B.O.D.

**TABLE VI.—Effect of Flash Pasteurization at 60° C. on B.O.D.**

| Sample | 5-Day B.O.D. (p.p.m.) | | | |
|---|---|---|---|---|
| | Unpasteurized | | Pasteurized | |
| | Low Dil. | High Dil. | Low Dil. | High Dil. |
| Industrial Raw | 760 | 840 | 720 | 720 |
| Indust. Clar. Eff. | 295 | 280 | 315 | 340 |
| Pr. Filt. Eff. | 240 | 260 | 230 | 240 |
| Pr. Filt. Clar. Eff. | 130 | 140 | 110 | 110 |
| Domestic Raw | 328 | 310 | 302 | 305 |
| Dom. Clar. Eff. | 125 | 130 | 125 | 125 |
| *Sec. Filt. Eff. | 64 | 48 | 24 | 21 |
| *Sec. Filt. Clar. Eff. | 55 | 31 | 18 | 20 |
| *Final Effluent | 23 | 17 | 10 | 9 |

* Denotes samples which were in nitrification stage.

## Chlorination vs. Pasteurization

It has been reported that chlorination of final effluents from biochemical treatment plants frequently results in marked reductions of B.O.D. It was suspected by the authors that chlorination might accomplish results similar to those obtained by pasteurization through destruction of the nitrifying flora. Therefore, a series of samples were subjected to B.O.D. analysis using pasteurized, chlorinated, and unpasteurized portions. Duplicate bottles were set up in all cases to determine the extent of nitrification in the 5-day period.

The results are given in Table VII and show that practically identical B.O.D. values were obtained on the pasteurized and chlorinated samples and that no appreciable nitrification occurred in these cases. On the other hand, the B.O.D. of the unpasteurized samples was much higher and the increase could be accounted for largely by the oxygen required in nitrification. These data show that pasteurization as recommended is no more drastic in its action than chlorination, and that both allow a reasonable development of the carbonaceous B.O.D. which remains, provided the dilution water used is properly seeded. In the chlorination studies all excess chlorine was dissipated with sodium sulfite before setting up the B.O.D. tests.

## Discussion

The B.O.D. of sewage treatment plant effluents is normally determined for two distinct reasons, namely, to ascertain the removals accomplished by the treatment processes and to gain information on the loading of B.O.D. on the receiving body of water.

The case for modifying the B.O.D. test to obtain the former information has been presented. It may be argued that the situation at Sioux Falls was exceptional and that in normal plant effluents such differences would not exist. Such is not the condition, however, as the authors know of other plants in this country which encounter similar troubles. Townend (3) has indicated trouble with final effluent B.O.D. at the Mogden plant in England and correlates the trouble with nitrifi-

**TABLE VII.—Effect of Pasteurization and of Chlorination on B.O.D. of Partially Nitrified Effluents**

| Conditions | Dilution (%) | Results in P.P.M. | | | |
|---|---|---|---|---|---|
| | | B.O.D. | $\Delta NO_2$-N | $\Delta NO_3$-N | Nitrogenous B.O.D. |
| *Secondary Filter Effluent* | | | | | |
| Unpast. | 20 | — | +0.33 | +0.50 | — |
| Unpast. | 10 | 72 | +0.22 | +1.09 | 57 |
| Unpast. | 5 | 41 | −0.01 | +0.22 | 21 |
| Past. | 20 | 24 | +0.11 | +0.05 | — |
| Past. | 10 | 24 | −0.01 | +0.04 | — |
| Past. | 5 | 26 | +0.11 | +0.01 | — |
| Chlor. | 20 | 22 | +0.04 | +0.07 | — |
| Chlor. | 10 | 25 | +0.02 | +0.01 | — |
| Chlor. | 5 | 22 | +0.06 | +0.03 | — |
| *City Final Effluent* | | | | | |
| Unpast. | 20 | >37 | −0.17 | +1.20 | 24 |
| Unpast. | 10 | 32 | −0.24 | +0.47 | 13 |
| Past. | 20 | 10 | 0.00 | −0.26 | — |
| Past. | 10 | 9 | −0.02 | −0.05 | — |
| Chlor. | 20 | 9 | −0.01 | −0.10 | — |
| Chlor. | 10 | 8 | −0.01 | +0.05 | — |
| *Army Final Effluent* | | | | | |
| Unpast. | 20 | 17 | +0.64 | 0.00 | 11 |
| Unpast. | 10 | 13 | +0.04 | −0.10 | — |
| Past. | 20 | 7 | 0.00 | −0.22 | — |
| Past. | 10 | 6 | +0.01 | −0.27 | — |
| Chlor. | 20 | 6 | 0.00 | −0.09 | — |
| Chlor. | 10 | 6 | 0.00 | −0.08 | — |

Δ—Increase in nitrite and nitrate nitrogen during incubation test.

cation. Furthermore, it must be conceded that exaggerated conditions are the ones most prone to demonstrate weaknesses or shortcomings in methods of analysis. It is logical to conclude that a system of analysis which is shown to be unsatisfactory under a given set of conditions will undoubtedly prove unreliable at other locations where similar conditions are attained, the difference being largely one of degree as influenced by intensity of nitrifying conditions.

It is questionable whether we should modify the present method of determining the B.O.D. of final effluents in order to ascertain the loading imposed upon the receiving waters. It can be argued that it is only the carbonaceous B.O.D. which is significant, as it is the only form which abstracts dissolved oxygen from the water and renders such oxygen nonavailable. The nitrogenous B.O.D., on the other hand, abstracts dissolved oxygen from the water but converts a

major part of it into forms (nitrites and nitrates) which act as oxygen reserves and which will yield oxygen to prevent or delay the development of anaerobic conditions.

One consideration which must be taken into account is, of course, whether the receiving waters are expected to maintain dissolved oxygen concentrations above certain minimum values or whether prevention of the development of anaerobic conditions is the basic consideration. The situation is not as clearly defined as it may seem. To illustrate this point, dissolved oxygen data obtained on the Big Sioux River under ice cover, during the winters of 1942 and 1945, are presented in Table VIII.

It will be noted that, though the B.O.D. of the effluents during February, 1942 was somewhat higher than in January, 1945, the river flow was also higher during the former period and B.O.D. loadings per unit volume of dilution water were nearly the same. In spite of this, the dissolved oxygen conditions in the river were entirely different. This would seem to indicate that a considerable difference existed in the nature of the B.O.D. during February, 1942 as compared to January, 1945.

Although no nitrogen data were obtained on the final effluent during the former period, it is strongly suspected that oxidized forms of nitrogen were lacking. During the winter of 1941–42, the Sioux Falls plant was severely overloaded and it is reasonable to assume that nitrification was very limited and that the B.O.D. shown by final effluent analysis was due largely to stabilization of carbonaceous residues. In the period between 1942 and 1945 considerable expansion of plant facilities was made and studies conducted during the winter of 1945 showed nitrification to be quite extensive and a large part of the effluent B.O.D. was due to nitrogenous oxidation.

These data naturally raise the question as to just how valuable are our B.O.D. data for determining the loading on rivers, lakes and streams. The authors have concluded that it is questionable whether nitrogenous B.O.D. data obtained at 20° C. can be translated to natural conditions at much lower temperatures.

For the time being, it would appear that the B.O.D. of final effluents in which nitrification is a significant factor should be determined in two ways: One designed to inhibit nitrification so as to allow measurement of carbonaceous B.O.D. for purposes of determining plant removals and efficiencies and, another, the conventional

**TABLE VIII.—Comparison of Final Effluent B.O.D. and Dissolved Oxygen in the Big Sioux River During Two Winter Seasons**

| Date | Effluent B.O.D.* (p.p.m.) | River Flow (c.f.s.) | Dissolved Oxygen (p.p.m.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Sta. 1† | Sta. 2 | Sta. 3 | Sta. 4 | Sta. 5 |
| 2- 4-42 | 98 | 34.2 | 12.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 108 | 36.7 | 12.3 | 0.0 | 0.0 | 0.0 | 2.3 |
| 18 | 67 | 34.2 | 15.2 | 2.2 | 0.6 | 2.2 | 3.9 |
| 23 | 48 | 34.2 | 14.3 | 0.0 | 2.6 | 3.6 | 1.6 |
| 1- 4-45 | 45 | 25.8 | 12.4 | 9.8 | 9.6 | 7.0 | 7.0 |
| 11 | 50 | 20.2 | 10.7 | 7.3 | 6.8 | 7.6 | 6.8 |
| 18 | 60 | 23.3 | 11.4 | 9.4 | 7.9 | 7.7 | 6.8 |
| 25 | 47 | 23.3 | 10.2 | 8.2 | 6.3 | 6.4 | 8.5 |
| 2- 1-45 | 61 | 25.8 | 12.7 | 10.6 | 9.9 | 9.6 | 9.0 |

* Effluent B.O.D.—Average for three days prior to sampling of the river.
† Sta. 1 located on river above outfall sewer of treatment plant.

method for determining loadings on receiving bodies of water.

## Summary

1. The biochemical oxygen demand of effluent waters from biological treatment processes may be largely due to nitrogenous oxidation.

2. Pasteurization or chlorination of such effluent waters will arrest nitrification and allow carbonaceous B.O.D. to be measured, provided a seeded dilution water is used and excess chlorine has been destroyed.

3. Flash pasteurization at 60° to 80° C. with subsequent cooling to 20° C. has been found to be a satisfactory procedure for destroying the activity of the nitrifying organisms.

4. The measurement of residual carbonaceous B.O.D. without interference from nitrogenous B.O.D. allows determination of plant efficiencies in terms of plant loadings.

## References

1. Theriault, E. J., "The Oxygen Demand of Polluted Waters," *Public Health Bull.*, No. 173, 147–149 (1927).
2. Mohlman, F. W., "Nitrification" an Editorial, THIS JOURNAL, **10**, 792 (1938).
3. Townend, C. B., "Ten Years Operation of the West Middlesex Works at Mogden, England," THIS JOURNAL, **17**, 1146 (1945).

# PREAERATED RAW SLUDGE RECIRCULATION INCREASES PRIMARY SEDIMENTATION EFFICIENCY AT DENVER

By C. P. Gunson

*Superintendent, Sewage Treatment Plant, Denver, Colorado*

The Denver sewage treatment plant was placed in operation in December, 1937. Designed to treat a flow of 54 m.g.d., the plant comprises the following units (Figure 1):

(*a*) One Venturi meter; capacity 120 m.g.d.

(*b*) Three bar screens equipped with Rex cleaning equipment and screening shredders.

(*c*) Two grit chambers equipped with Rex grit removal equipment and affording a velocity of 1 f.p.s. when both in operation at the 54-m.g.d. rate.

(*d*) A preaeration tank equipped for spiral flow air diffusion and for skimming of grease; detention period 15 min. at the design flow; air capacity for 0.02 cu. ft. per gal. at design rate.

(*e*) A flocculation tank of the same capacity as the preaeration tank and equipped with Dorr flocculation equipment.

(*f*) Four Dorr clarifiers of 140-ft. diameter, affording a detention time of 1.96 hr. at the design flow of 54 m.g.d.

(*g*) Three pairs of magnetite filters. (These units were last used as filters in the summer of 1942, at which time the equipment was dismantled and the tanks put to use as post-chlorination contact tanks.)

(*h*) Four 95-ft. diameter by 30-ft. deep digesters, all equipped with P.F.T. floating covers; design capacity 2 cu. ft. per capita.

(*i*) Sixty-eight open sludge drying beds having natural underdrainage; each unit 80 ft. by 100 ft.

(*j*) A chemical control building for the application of lime and ferric chloride (by Scott-Darcey Process). (These facilities were provided for use at times of critical stream conditions; their operation has not yet been justified except on a trial basis because of cost considerations.)

When the continuous operation of the magnetite filters was suspended in 1939, several experimental efforts were made to employ the preaeration, flocculation and sedimentation units so as to secure improved results over those normally expected from primary treatment. These experiments were to no avail, however, until March, 1940 when a procedure was tried involving the return of part of the raw sludge from the primary tanks to the sewage entering the preaeration tanks.

Twenty-five per cent of the raw sludge was thus recirculated, being thoroughly mixed with the sewage in the course of preaeration. The sewage-sludge mixture was then flocculated and put through the primary sedimentation tanks, with interesting and promising results.

## Transitional Observations

Within 24 hours after the commencement of the raw sludge return the sedimentation tanks showed evidence of slight septicity. After another 24 hours this condition abated but there was not at this time any indication of improvement in solids removal.

The recirculated sludge was dark brown in color at the beginning of the experiment but, as the study progressed

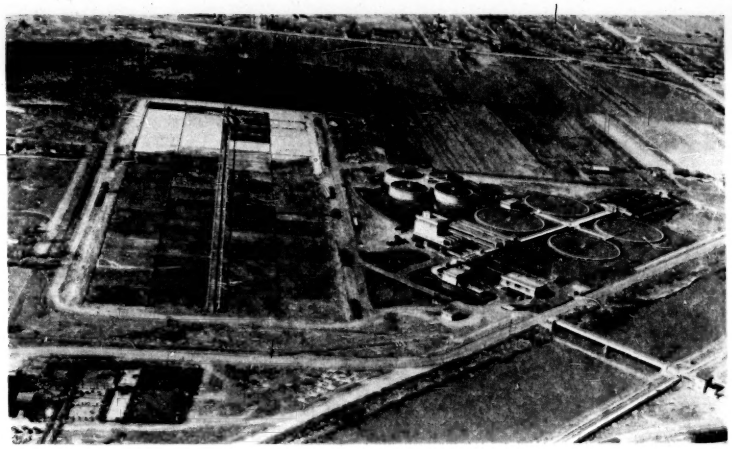

FIGURE 1.—Air view of Denver sewage treatment plant: (1) Administration Bldg., (2) Screen House, (3) grit chambers, (4) Chemical Bldg., (5) preaeration and flocculation tanks (6) primary settling tanks, (7) magnetite filters (now dismantled), (8) sludge digestion tanks, (9) sludge drying beds.

for a 10-day period, the color changed to a very light brown.

Daily determinations of suspended solids were made of the sewage before admixture of return sludge and of the preaerated and flocculated sewage-sludge mixture entering the settling tanks. It was not until the solids concentration of the flocculated mixture almost doubled the solids content of the raw sewage that improved removal of suspended matter was effected by sedimentation.

The average removal of suspended solids before the raw sludge return experiment was about 70 per cent. After 10 days of sludge return the removal of solids improved to about 80 per cent. This highly satisfactory removal held for the next 12 days, after which there followed 2 days of relatively poor results before removals in the 80 per cent range resumed.

This interesting cycle repeated itself for the next nine months. During this period there was no overall improvement in B.O.D. removal.

After careful observation and study of this cycle it was decided that the heavy floc created by the returned sludge was gradually broken down by the continuous recirculation until a portion of it became so disintegrated that it would no longer settle. When this point was reached the fines passed through the sedimentation tanks in the effluent, thus causing the poor removals. After these non-settleable particles were discharged the floc would then regain its density and a period of good removals would ensue.

It followed from this reasoning that if the cyclical disintegration of the floc could be controlled, a beneficial "levelling action" could be obtained. It was realized that such control would probably require the sacrifice of some of the higher efficiencies but this cost was not deemed excessive if the periods of low removal could be eliminated.

### Modified Experimental Procedure

In an effort to attain the above aims, a temporary wood box, equipped with

air diffusion grids, was built at the inlet end of the preaeration tanks for the purpose of giving preliminary aeration to the return sludge before admixture with the sewage. This box was 18 ft. long, 12 ft. wide and 5 ft. 6 in. deep, having sufficient volume to afford a retention time of 1 hour for the return sludge flow.

The results of this preliminary aeration of the recirculated sludge were immediately evident. Removal of suspended solids at the sedimentation tanks remained consistently at about 78 per cent. Furthermore, it was noted that B.O.D. removal also improved markedly, increasing to about 54 per cent from its original average of about 43 per cent.

After the temporary recirculated sludge aeration box was in operation for a short time it was found that a great many solids and rags deposited therein, regardless of the amount of turbulence induced by the applied air. The rate of air application was approximately 3 cu. ft. per gal. of sludge. As the box filled with solids, the detention time was proportionately reduced until it became necessary to remove the accumulation.

The first time this was done the box was washed clean. Upon restoration to service thereafter a definite reduction was noted in B.O.D. removal and several days passed before good removals again took place. Particular attention was then paid to the relationship between the condition of the sludge aeration box and the degree of B.O.D. removal.

These observations led to the conclusion that if the walls and floor of the box were not washed clean, most of the accumulated solids could be removed without affecting the B.O.D. removal. It was also found that the removals of both suspended solids and B.O.D. were reduced if the contents of the sludge box were kept in suspension by violent aeration with a very high rate of air application. Best results were secured when the returned raw sludge was agitated gently, the heavy solids and rags being removed daily without draining the box.

## Experimental Results

Table I shows a comparison of yearly average removals of suspended solids and B.O.D. for the period 1939–42, inclusive. These data include a full year of results before the recirculation of raw sludge was practiced, the results during the experimental work and the results accomplished during 1942 when the temporary sludge aeration box was in service.

It will be noted that there was a progressive increase in sewage flow during the 4-year period and that the raw sewage strength increased sharply in 1940, remaining fairly constant for the period 1940–42, inclusive.

**TABLE I. Comparison of Solids and B.O.D. Removals at Denver, Colo. Before and After Trial of Raw Sludge Recirculation**

| Year | Sewage Flow (m.g.d.) | Suspended Solids | | | | 5-Day B.O.D. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Raw (p.p.m.) | Settled (p.p.m.) | Removal | | Raw (p.p.m.) | Settled (p.p.m.) | Removal | |
| | | | | P.P.M. | Per Cent | | | P.P.M. | Per Cent |
| 1939 | 38.7 | 145 | 43 | 102 | 70.4 | 170 | 94 | 76 | 44.7 |
| 1940* | 40.8 | 200 | 45 | 155 | 77.5 | 213 | 123 | 90 | 42.5 |
| 1941† | 45.5 | 197 | 42 | 155 | 78.5 | 217 | 116 | 101 | 46.5 |
| 1942 | 53.1 | 196 | 37 | 159 | 81.1 | 222 | 91 | 131 | 59.0 |

* Return of 25 per cent of raw sludge to inlet of preaeration tanks begun in March, 1940.
† Temporary return sludge aeration box placed in operation in early summer of 1941.

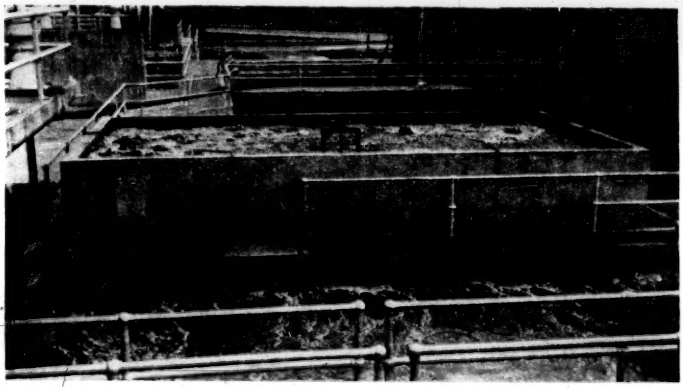

FIGURE 2.—Permanent return sludge aeration tank.

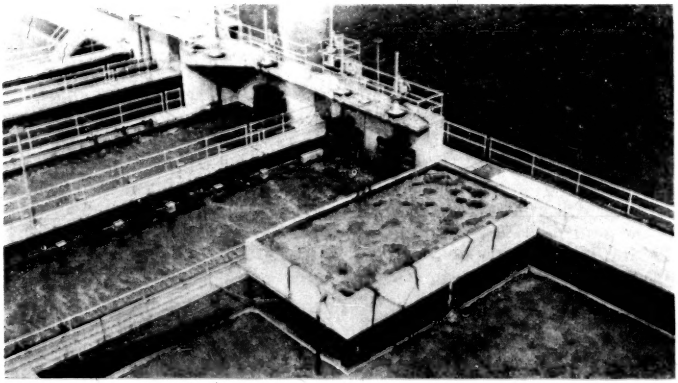

FIGURE 3.—Permanent return sludge aeration tank in foreground; sewage preaeration tanks at left.

## Permanent Facilities

The experimental return sludge aeration box was kept in service until March, 1943, when it was replaced by a permanent concrete tank (Figures 2 and 3). In the course of this work, it was necessary to suspend preaeration of the return sludge for a 60-day period, the return sludge being sent directly to the sewage preaeration tanks as was done in the first experiments. Immediately upon elimination of the return sludge preaeration step, the B.O.D. removal dropped to 45 per cent and less and the solids removal returned to the fluctuating cycle previously described.

The new concrete tank is 26 ft. long, 16 ft. wide and was first placed into operation with a 3-ft. water depth. Upon placing it in service, the same "breaking in" period of about 10 days

**TABLE II.—B.O.D. and Suspended Solids Removals in 1944, 1945 and 1946. Permanent Sludge Preaeration and Recirculation Facilities in Operation**

| Date | Solids | | | B.O.D. | | | Sewage Flow (m.g.d.) |
|---|---|---|---|---|---|---|---|
| | Raw (p.p.m.) | Settled (p.p.m.) | Removal (%) | Raw (p.p.m.) | Settled (p.p.m.) | Removal (%) | |
| *1944* | | | | | | | |
| Jan. | 248 | 54 | 78.2 | 299 | 144 | 51.8 | 50.4 |
| Feb. | 291 | 64 | 78.1 | 290 | 143 | 50.7 | 52.6 |
| Mar. | 198 | 52 | 73.8 | 251 | 128 | 48.6 | 52.4 |
| Apr. | 199 | 52 | 74.0 | 232 | 113 | 51.2 | 48.2 |
| May | 176 | 46 | 73.8 | 229 | 119 | 48.1 | 51.3 |
| June | 162 | 40 | 75.3 | 213 | 107 | 49.7 | 47.3 |
| July | 189 | 45 | 75.8 | 209 | 106 | 49.3 | 45.3 |
| Aug. | 162 | 36 | 77.7 | 219 | 93 | 57.6 | 51.1 |
| Sept. | 165 | 39 | 76.4 | 206 | 93 | 54.8 | 55.6 |
| Oct. | 216 | 36 | 83.3 | 239 | 88 | 63.1 | 53.3 |
| Nov. | 202 | 46 | 77.2 | 238 | 110 | 53.8 | 50.9 |
| Dec. | 192 | 48 | 75.1 | 253 | 118 | 53.3 | 50.5 |
| Ave. | 200 | 47 | 76.5 | 240 | 113 | 52.7 | 50.7 |
| *1945* | | | | | | | |
| Jan. | 207 | 62 | 70.0 | 243 | 123 | 49.3 | 51.6 |
| Feb. | 190 | 76 | 60.9 | 246 | 149 | 40.8 | 51.4 |
| Mar. | 172 | 59 | 65.6 | 211 | 109 | 48.2 | 52.5 |
| Apr. | 220 | 63 | 71.3 | 251 | 119 | 52.6 | 50.5 |
| May | 201 | 57 | 71.6 | 254 | 111 | 56.4 | 50.9 |
| June | 190 | 52 | 72.6 | 228 | 106 | 53.4 | 51.6 |
| July | 189 | 53 | 72.0 | 189 | 90 | 51.6 | 56.9 |
| Aug. | 196 | 54 | 71.8 | 172 | 81 | 52.9 | 57.2 |
| Sept. | 192 | 52 | 73.0 | 194 | 94 | 51.6 | 54.0 |
| Oct. | 187 | 65 | 65.0 | 198 | 109 | 44.9 | 47.4 |
| Nov. | 191 | 64 | 66.5 | 214 | 114 | 46.7 | 43.8 |
| Dec. | 212 | 54 | 74.5 | 247 | 111 | 55.1 | 48.3 |
| Ave. | 195 | 59 | 69.6 | 220 | 109 | 50.3 | 51.3 |
| *1946* | | | | | | | |
| Jan. | 204 | 42.7 | 79.0 | 247 | 114 | 53.6 | 47.3 |
| Feb. | 235 | 56.0 | 76.2 | 274 | 143 | 47.7 | 47.5 |
| Mar. | 208 | 45.8 | 77.9 | 276 | 139 | 49.5 | 46.9 |
| Apr. | 216 | 48.5 | 77.6 | 246 | 106 | 56.7 | 47.4 |
| May | 202 | 47.9 | 76.3 | 237 | 100 | 57.9 | 50.1 |
| Ave. | 212 | 48.0 | 77.4 | 256 | 120 | 53.1 | 47.8 |

was required before results could be observed, as was noted when the experimental box was put into operation in 1941. After the initial conditions stabilized, however, it was found that the permanent installation did not give as good results as did the temporary sludge aeration box.

The most obvious difference between the temporary and permanent sludge aeration boxes was in the liquor depth, which was 5 ft. 6 in. in the former and 3 ft. in the latter. The liquor depth was then increased to 3 ft. 6 in., the maximum possible without major reconstruction, after which B.O.D. and solids removals approached the favorable accomplishment of the deeper experimental unit.

Table II gives results of operation with the permanent return sludge aeration tank in service for the years 1944–

45 and the first five months of 1946. A significant saving in applied air was effected with the new tank; present air consumption is only 0.3 cu. ft. per gal. of return sludge as compared to 3 cu. ft. per gal. in the temporary wood box.

It will be noted that the removals of B.O.D. and suspended solids during certain months of 1945 were markedly lower than in 1944 and 1946. This was a result of industrial wastes originating at the Denver Ordnance Plant, which were discharged to the municipal sewage works during parts of 1945 while the waste treatment facilities at the ordnance plant were being rebuilt.

It is intended to reconstruct the existing return sludge preaeration tank so as to increase the liquor depth to 5 ft. 6 in. With this change, it is anticipated that B.O.D. removals can be achieved approaching 60 per cent in summer and 55 per cent in winter.

# CONTROL OF SEWER USAGE AT DETROIT, MICHIGAN

By Clyde L. Palmer

*Senior Associate Engineer of Sanitary Design, City Engineer's Office, Detroit, Michigan*

Since the time when sewers were first provided for the purpose of removing human wastes and storm water from the domestic environment, an increasing number of additional uses have been made of this service. The necessity for control of the usage of public sewers arises principally because of the unusual and diversified demands to which a sewer system and sewage treatment plant may be subjected by the introduction of industrial or commercial type wastes into a system primarily intended to dispose of domestic sanitary wastes.

## Theory of Proposed Control at Detroit

The capacity of sewage works to absorb the unusual demands caused by industrial or commercial type wastes depends upon the several factors of design and plan of the sewer system and the type of treatment process in use. Theoretically, any rules or regulations made for the purpose of sewer use control should be statements defining the available capacity or ability of the collection and treatment facilities for absorbing the demands of industrial or commercial type wastes.

The composition of industrial or commercial type wastes in a large manufacturing community, such as Detroit, is of great complexity in all degrees of concentration, being characteristically variable and changing radically as new materials and new processes are put into use.

Because of the variable characteristics of industrial or commercial type wastes, the "Standards and Regulations" for sewer use control should avoid as far as possible the naming of specific materials and adhere to the principle of defining the characteristics and effects which are to be subjected to control.

## Local Conditions Governing

The Detroit conditions for which the "Standards and Regulations" are designed to apply are, briefly, as follows:

1. Geographically, Detroit is located at the source of the Detroit River, which flows between Lake St. Clair and Lake Erie. The Detroit River, with an average flow of about 180,000 c.f.s., receives the storm water run-off of the area together with the effluent from the sewage treatment plant. Downstream from Detroit are many smaller communities which obtain their raw water supply from the Detroit River or Lake Erie. The Detroit water supply is slightly alkaline, with an average pH value of about 7.6.

2. As to sewerage, the existing conduits are constructed on the combined plan, with minimum velocities of 3 ft. per sec. The larger physical structures of the system are built of either brick masonry or concrete, the smaller, of vitrified or concrete pipe.

3. The storm flows are discharged to the Detroit and Rouge Rivers. The dry weather flow is diverted through mechanical regulators to the sanitary interceptors leading to the sewage treatment plant.

4. The sewage treatment plant consists of plain sedimentation, vacuum filtration, incineration, and chlorination, with facilities for digestion of one-eighth of the sludge load.

## Definitions Adopted

For purposes of clarity in the application of the "Standards and Regulations," the following definitions are intended:

*Sewage* is all liquids and wastes flowing in the sewers, and may be a mixture in any proportion of the following three components: sanitary wastes, industrial or commercial wastes, and storm water.

*Storm water* is that part of the rainfall that reaches the sewers as run-off from the natural land surface, building roofs or pavements, or as ground water infiltration.

*Sanitary wastes* are the solid and/or liquid human wastes only, including such quantities of water as may be used for the transportation thereof.

*Industrial or commercial type wastes* are the liquid and/or solid wastes from industrial or commercial processes. It should be noted that such wastes as ground garbage or laundry water, etc. originating in a home will be included in this classification.

## Practical Applications

The proposed "Standards and Regulations" for controlling the use of Detroit sewers place no limitations on sanitary wastes as defined above.

The "Standards and Regulations" are designed to permit the maximum service to the producer of industrial or commercial type wastes without causing damage to or restricting the function of the sewer system or sewage treatment plant, and without endangering public health and safety or being inimical to the public interest.

Sewer use control as proposed for Detroit will employ an ordinance prohibiting the discharge into the sewerage system of any "deleterious" material as defined by the "Standards and Regulations" established by the City Engineer.

The proposed "Standards and Regulations" for controlling the use of Detroit sewers through the definition of "deleterious" material are as follows:

*Standards and Regulations Controlling the Discharge of Industrial or Commercial Type Wastes into the Detroit Sewer System*

Any waste will be considered "deleterious" that may cause damaging effects as stated under "General Conditions" and/or does not conform to the limitations stated under "Specific Conditions."

*General Conditions:*

(*a*) Chemical reaction, either directly or indirectly, with the materials of construction to impair the strength or durability of sewer structures.

(*b*) Mechanical action that will destroy or damage the sewer structures.

(*c*) Restriction of the hydraulic capacity of sewer structures.

(*d*) Restriction of the normal inspection or maintenance of the sewer structures.

(*e*) Placing of unusual demands on the sewage treatment equipment or process.

(*f*) Limitation of the effectiveness of the sewage treatment process.

(*g*) Danger to public health and safety.

(*h*) Obnoxious conditions inimical to the public interest.

*Specific Conditions:*

(*a*) Acidity or alkalinity must be neutralized to a pH of 7.0 as a daily average on a volumetric basis, with a maximum temporary variation of pH 5.0 to 10.0.

(*b*) Must not contain more than 10 p.p.m. of the following gases: hydrogen sulfide, sulfur dioxide, nitrous oxide, or any of the halogens.

(*c*) Must not contain any explosive substance.

(*d*) Must not contain any flammable substance with a flash point lower than 187° F.

(*e*) Must have a temperature within the range of 32° to 150° F.

(*f*) Must not contain grease or oil or other substance that will solidify or become viscous at temperatures between 32° and 150° F.

(*g*) Must not contain insoluble substance in excess of 10,000 p.p.m. or exceeding a daily average of 500 p.p.m.

(*h*) Must not contain total solids (soluble and insoluble substance) in excess of 20,000 p.p.m. or exceeding a daily average of 2,000 p.p.m.

(*i*) Must not contain soluble substance in concentrations that would increase the viscosity to greater than 1.1 specific viscosity.

(*j*) Must not contain insoluble substance having a specific gravity greater than 2.65.

(*k*) Must not contain insoluble substance that will fail to pass a No. 8 Standard sieve, or having any dimension greater than ½ inch.

(*l*) Must not contain gases or vapors either free or occluded, in concentrations toxic or dangerous to humans or animals.

(*m*) Must not have a chlorine demand greater than 15 p.p.m.

(*n*) Must not contain more than 100 p.p.m. of any antiseptic substance.

(*o*) Must not contain phenols in excess of 0.005 p.p.m.

(*p*) Must not contain any toxic or irritating substance which will create conditions hazardous to public health and safety.

(*q*) Must not contain in excess of 100 p.p.m. or exceed a daily average of 25 p.p.m. of any grease or oil or any oily substance.

All of the preceding "Standards and Regulations" are to apply at the point where industrial or commercial type wastes are discharged into a public sewer. Furthermore, all chemical and/or mechanical corrective treatment must be accomplished to practical completion before this point is reached.

## Conclusion

The request for a definite statement as to the quality of industrial and commercial type wastes that may safely be discharged into a public sewer system has come generally from the producers of this type of waste, in their desire to co-operate and assume their proper responsibility.

The "Standards and Regulations" presented herein are intended as a statement of the maximum service that can be extended to the producers of industrial and commercial type wastes, consistent with the limitations of the sewage collection and treatment facilities and fair public policy. Inasmuch as very little information of this nature has appeared in the literature, constructive criticism on the subject of this article would be welcomed.

# EFFECTS OF COPPER-BEARING WASTES ON SLUDGE DIGESTION *

By H. T. Rudgal

*Superintendent, Sewage Treatment Plant, Kenosha, Wis.*

The Kenosha sewage treatment plant experienced serious sludge digestion troubles in 1940 and 1943. On both occasions the difficulties were caused by excessive concentrations of copper in the plant digesters. The source of copper in each case was found to be copper bearing pickling and rinse water wastes from a large copper and brass products industry.

The Kenosha plant is now completing its sixth year of operation, during which time varying amounts of copper have always been present in the sewage and in the raw and digester sludges. It may be of interest and value to review the facts pertaining to copper and its effects on sludge digestion at Kenosha.

## Early Experience

Sewage treatment operations were started in August, 1940. During the first month of sludge digestion, gas production was very poor, averaging only 0.7 cu. ft. per lb. of volatile matter added to the digesters. As the digesters were started without seed sludge, the poor digestion results at this time were not considered to be serious. When the poor digestion continued, however, investigations and research were started to determine the cause.

Every industrial plant in the city was visited and a recheck made on the amount and nature of all industrial wastes being discharged into the sewer system. By process of elimination, laboratory checks and data obtained, it was concluded that copper present in the processing wastes of a large brass industry must be the toxic element affecting the sludge digestion process.

To try to prove quickly that the copper-bearing wastes, which also included considerable oil and grease, were the cause of the unsatisfactory sludge digestion, it was decided to eliminate these wastes from the flow reaching the plant. This was done by by-passing directly to Lake Michigan, without treatment, the intercepting sewer carrying the copper and oily wastes, together with about 35 to 40 per cent of the city's domestic sewage flow.

Originally this procedure was to be a temporary measure, but unfortunately the necessity for continuance of this by-passing practice still exists, so that since October, 1940, the plant has been operated for the treatment only of the balance of the city's sewage flow. In the interim, negotiations and litigation have been carried on, with the matter finally reaching the State Supreme Court. To date, however, the copper waste problem has not been settled.

## 1940 Studies

Figure 1 shows 1940 digestion data with respect to daily sludge gas production for 6 months starting with August 1. During the first 2½ months all of the city's sewage, including the copper and oily wastes, received treatment at the plant. It is very evident that during this period digestion results were very poor. Gas production during this time averaged only 2,600 cu. ft. per day or approximately 0.5 cu. ft. per lb. of volatile solids added to the digesters.

* Presented at 18th Annual Meeting, Central States Sewage Works Assn.; Lafayette, Ind.; June 13–14, 1946.

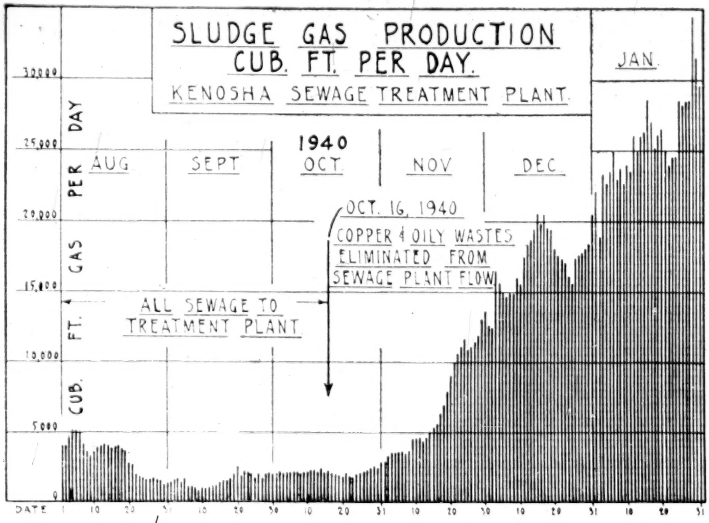


FIGURE 1.—Digester gas production at Kenosha in 1940–41, showing influence of copper in sludge.

During the time of poor sludge digestion, the copper concentration in the digesters gradually increased. A September, 1940 analysis of digester contents showed 1,400 p.p.m. Cu to be present. In October, the copper had increased to 2,500 p.p.m. in the raw sludge and over 3,000 p.p.m. in the digesters. Obviously, from the digestion results obtained, this concentration of copper was just too much for the digesters to assimilate without a serious detrimental effect on biological conditions within the digesters.

On October 16, 1940, the sewer carrying the copper and oily wastes was diverted by plugging the orifice which connected this line with the intercepter leading to the sewage treatment plant.

At about the same time a considerable amount of sludge was removed from the digesters in order to help reduce the copper concentration in these units. From Figure 1 it is apparent that within 10 days after the elimination of the copper wastes from the sewage flow, gas production improved slightly and continued to improve slowly but steadily from then on.

During November, gas production increased to 4 times that in October but was still at a rate of only 2.05 cu. ft. per lb. volatile matter. During the following months of December, January and February, digestion was further improved so that for these three months the gas production rate was 7.0, 10.1, and 11.3 cu. ft. per lb. volatile matter added to the digesters, respectively.

This was conclusive proof that the copper- and oil-bearing wastes, in the quantities received and removed at the sewage treatment plant, had been the inhibiting factors and the cause of the previous unsatisfactory sludge digestion results.

### 1943 Studies

In 1943 there was a recurrence of digestion troubles. Again copper and

brass processing wastes, but from a new source—a war industry—produced conditions at the sewage plant whereby sludge digestion was once more very seriously affected.

The war industry was placed into operation in July, 1942, for the production of shells and ammunition components. Copper and fatty wastes from this plant were routed to the by-passed sewer which was still receiving and conveying the copper wastes from the other brass works.

It was noted during the latter part of January, 1943 that digestion efficiency was again dropping off. A check of the copper content of the raw and digester sludges established the fact that large quantities of copper-bearing wastes were again present in the sewage being received at the treatment plant.

Since the brass companies' wastes were supposedly by-passed and excluded from the treated sewage flow, it was assumed that some local industry had changed manufacturing processes to include the use of pickling and copper plating.

A phone survey of manufacturing plants, other than the brass companies, disclosed that no new manufacturing processes had been started. To make sure of this fact, however, certain plants were inspected and samples taken and analyzed of all industrial waste waters, especially those involving pickling and plating. The investigations served to eliminate these particular plants as being the source of the copper wastes.

The next step, which required about two weeks' time, was to analyze samples taken from various parts of the sewer system. In this way the source of copper wastes was finally traced to a section of the sewer system adjacent to the new brass plant.

The internal sewer system of this plant, which started operation in July, 1942, had become plugged by its own wastes, and sometime after January 7, 1943, the copper and fatty wastes had been diverted to a new connection, into a sewer contributing to the sewage treatment plant flow. Incidently, the permit for construction of the new sewer connection had been issued for a water overflow line and not for copper-bearing wastes.

An analysis of the wastes being discharged at this location showed over 300 p.p.m. copper to be present. With the search for the new source of copper finally ended, steps were immediately taken to divert these wastes to flow to the by-passed sewer and this work was completed on February 27, 1943.

At the sewage plant, the copper had already done its damage. Digester gas production had decreased from a normal of about 33,000 cu ft. per day to a low of 7,500 cu. ft. daily. In order to get the digesters back into satisfactory operating condition it was necessary to remove all sludge from one digester and also remove the bottom sludge from the other, in order to reduce its copper content.

Figure 2 shows daily gas production for six months, including the 1943 period of poor sludge digestion. The deleterious effect of copper wastes is very evident. The decrease in gas production is apparent in Figure 2 starting on February 10. Actually, according to gas production efficiency in cubic feet per pound volatile matter, the break from normal started on January 25, with digestion efficiency decreasing steadily thereafter until March 18.

On January 30 the bottom sludge in the digester had a copper content of about 500 p.p.m., or 0.5 per cent on a dry solids basis. Gas production at this time had decreased 27 per cent to 8 cu. ft. per lb. volatile matter added, whereas normal was 11 cu. ft.

By March 1 the maximum copper concentration had increased to approximately 1,300 p.p.m., or 1.3 per cent, dry solids basis. Gas production on this date had decreased 64 per cent

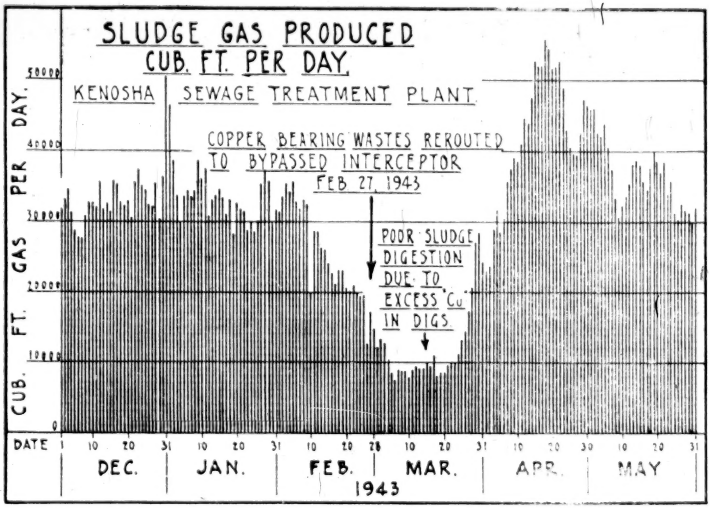
SLUDGE GAS PRODUCED
CUB. FT. PER DAY.
KENOSHA SEWAGE TREATMENT PLANT
COPPER BEARING WASTES REROUTED TO BYPASSED INTERCEPTOR FEB 27, 1943
POOR SLUDGE DIGESTION DUE TO EXCESS Cu IN DIGS
CUB. FT. GAS PER DAY.
50000
40000
30000
20000
10000
0
DATE
1 10 20 31 10 20 31 10 20 28 10 20 31 10 20 30 10 20 31
DEC. JAN. FEB. MAR. APR. MAY
1943

FIGURE 2.—Effect of copper wastes on digester gas production at Kenosha in 1943.

below normal, or to about 4 cu. ft. per lb. volatile matter.

From March 1–18, gas production remained quite uniform but at a low production rate. By the latter date, the cleaned digester was ready to be placed back into operation; with this unit in service gas production improved rapidly and was back to normal within a short time.

## Recent Observations

Before presenting other data showing the effects of copper on sludge digestion, certain facts relevant to copper-bearing industrial wastes should first be mentioned. The late Prof. C. R. Hoover, in the Eighth Biennial Report of the State Water Commission of the State of Connecticut, had this to say: "Copper has long been known to have deleterious effects on biological processes, but the insidious nature of the effect of small amounts of copper in sewage upon the decreased efficiency of the operation of sludge digestion has not been generally recognized."

As an illustration of Prof. Hoover's statement, Kenosha operating data should emphasize this fact. During the month of February, 1945, the sewage flow was 140 m.g. Wet sludge pumped to the digesters totaled 407,500 gal., while the dry solids in the sludge amounted to 207,500 lb. By copper tests of the raw sludge, the copper loading at the digesters during the month was determined to have been 770 lb. as Cu, or about 25 lb. copper per day. The insidious thing about this quantity of copper becomes more apparent upon converting the 770-lb. figure to parts per million as copper removed from the sewage, and as copper concentrated in the raw sludge and digester contents.

The 770 lb. copper per month is equivalent to only 0.7 p.p.m. removed from the sewage. In the wet sludge, however, the copper had become con-

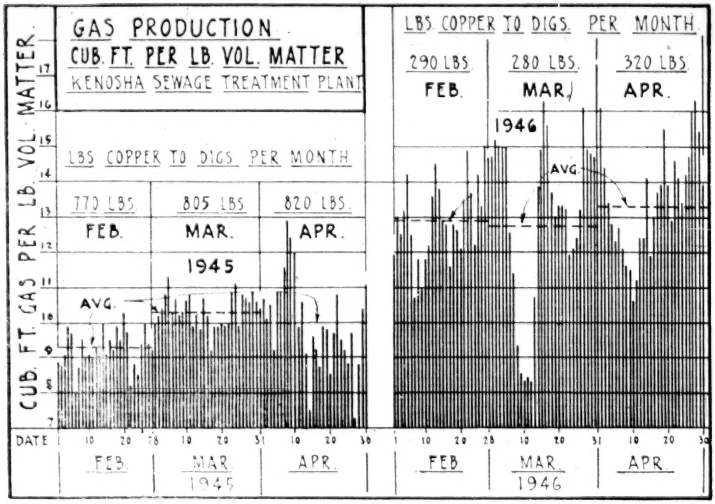


FIGURE 3.—Comparison of digestion efficiencies during identical periods in 1945 (heavy copper load) and in 1946 (light copper load).

centrated to 226 p.p.m., or over 320 times greater. With respect to copper in the dry solids of the raw sludge, the copper concentration was 3,710 p.p.m. or 0.37 per cent. In the digesters, the copper concentration had become stabilized at approximately 5,000 p.p.m. or 0.5 per cent dry basis. During this particular month (February, 1945), gas production was down to a rate of 9.3 cu. ft. per lb. volatile matter, or 15.5 per cent below the plant normal of 11 cu. ft. per lb. volatile matter added to the digesters.

The Kenosha operation staff is of the opinion that copper concentrations in sludges are better expressed as to their relationship to the dry solids in the sludge. This may be expressed as per cent copper in the dry solids or preferably as parts per million copper, dry solids basis. In this case 1 per cent copper is equal to 10,000 p.p.m.

The reasoning behind this conclusion may be illustrated in the following manner: For example, assume that the copper in sludge is reported as being 400 p.p.m. If the dry solids in this sludge are 4 per cent, the copper concentration on a dry solids basis is increased 25 times and is 10,000 p.p.m. If the sludge is 8 per cent dry solids, however, the copper concentration as dry solids is only one-half that present in the 4 per cent sludge, or namely 5,000 p.p.m., dry basis. In the case of the 4 per cent sludge, the 400 p.p.m. of copper present may seriously affect sludge digestion while in the other case digestion would be affected to a far lesser degree.

As another example, digester survey data are used. On a wet basis, the copper present in the Kenosha digester supernatant was 11 p.p.m. and in the bottom sludge 500 p.p.m. The solids in the supernatant were only 0.26 per cent, while in the bottom sludge the solids content was 12.3 per cent. The concentrations of copper present in the dry solids of these two liquors, however, were 4,250 p.p.m. in the super-

natant and 4,060 p.p.m. in the bottom sludge (both dry basis), or practically the same. From the latter copper figures it is evident that the copper concentration on the basis of dry solids was quite uniform throughout the digester. This fact is not at all evident when the copper content is expressed on a wet basis, with the copper figures being 11 and 500 p.p.m., respectively.

Furthermore, since sludge gas is produced only from the organic matter in the sludge, the relationship of copper to these solids is even a better criterion of copper concentration. At Kenosha, however, it is believed that copper concentration on the basis of total dry solids (not volatile solids) is a satisfactory means of expressing the copper content, and the records are maintained accordingly.

Figure 3 shows daily gas production rates in cubic feet per pound volatile matter added to the digesters for the months of February, March, and April during 1945 and 1946. These data are plotted to show how digestion efficiency increased as the copper loading to the digesters decreased.

For the three months in 1945, which period incidentally is prior to "V-J Day," copper loading to the digesters averaged 800 lb. per month. Gas produced during this time averaged 9.87 cu. ft. per lb. volatile matter.

For the same three months in 1946, the copper loading to the digesters had decreased to about 300 lb. per month, with an increase in digestion efficiency whereby gas produced averaged 13 cu. ft. per lb. volatile matter, an increase of 32 per cent over the same period in 1945. These data are interesting in that they cover two digestion periods, during which time the solids loadings to the digesters were approximately the same except for the copper present in the sludge.

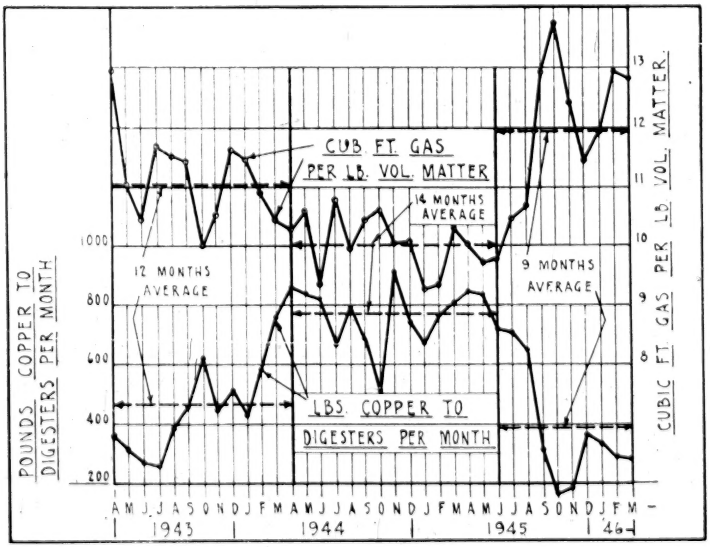


**FIGURE 4.—Relationship between copper content of raw sludge and digestion efficiency at Kenosha, April, 1943, to March, 1946.**

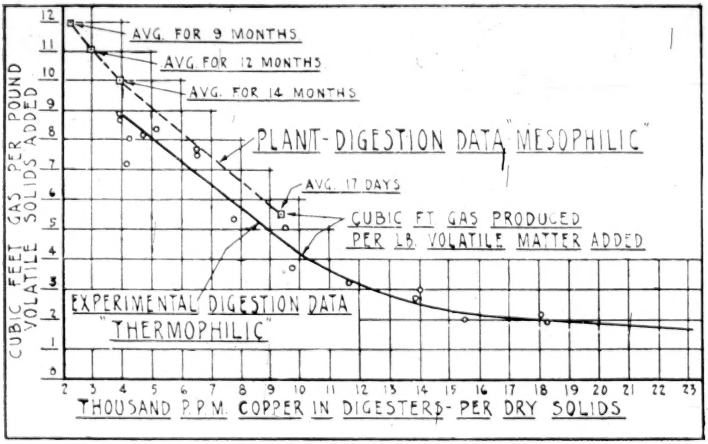
AVG. FOR 9 MONTHS
AVG. FOR 12 MONTHS
AVG. FOR 14 MONTHS
PLANT-DIGESTION DATA "MESOPHILIC"
AVG. 17 DAYS
CUBIC FT GAS PRODUCED PER LB. VOLATILE MATTER ADDED
EXPERIMENTAL DIGESTION DATA "THERMOPHILIC"
CUBIC FEET GAS PER POUND VOLATILE SOLIDS ADDED
THOUSAND P.P.M. COPPER IN DIGESTERS-PER DRY SOLIDS

FIGURE 5.—Relationship between copper concentration in digester contents and digestion efficiency at mesophilic and thermophilic temperatures.

Figure 4 shows average monthly digestion results from April, 1943 to March, 1946. In this chart are plotted data showing pounds copper present in the raw sludge as pumped to the digesters and related gas production data in cubic feet of gas per pound volatile matter added to the digesters.

From Figure 4 it is evident that there is a relationship between gas production and the amount of copper pumped to and present in the digesters. Except for the period from December, 1944 to June, 1945, this inverse relationship is very apparent and is particularly evident after June, 1945.

Breaking down and analyzing these data to cover three periods of 12, 14 and 9 months, respectively, it is found that with average copper loadings of 468, 770, and 386 pounds per month, the corresponding average gas production rates were 11.02, 10.0, and 11.95 cu. ft. per lb. volatile matter added to the digesters, respectively.

In Figure 5 are plotted plant digestion data with respect to cubic feet of gas produced per pound of volatile matter as related to copper concentrations in parts per million Cu (dry solids basis) of the digester contents. The squared points indicate gas production rates as computed for three separate periods of 9, 12 and 14 months, respectively, while the lower point indicates results obtained for 17 days during the 1943 sludge digestion trouble period.

These data clearly show that with Kenosha sludge and the copper present therein, a definite relationship between digestion efficiency and copper concentration in the digesters does exist.

### Thermophilic Experiments

In Figure 5 are also plotted thermophilic digestion data (circled points) which show the results obtained in 1945 with experimental thermophilic digestion of Kenosha sludge at 133° F., under increasing copper loading and concentration conditions. This test covered a period of 50 days, after 33 days were allowed for the experimental bottle digesters to become stabilized to normal operating conditions.

Details pertaining to the Kenosha thermophilic digestion experiments will not be discussed at this time, but it may suffice to state that from the data obtained and plotted it is apparent that even at thermophilic temperatures, copper had about the same relative inhibiting deleterious effect on sludge digestion.

## Summary

In concluding this discussion, certain items warrant reiteration and final review. From the data on digestion of copper-bearing sludge now at hand, it is easily understandable why digestion could not be started in 1940. In reporting the 1940 experiences and copper concentrations, determined at that time, it was stated that in October, 1940, the raw sludge contained over 2,500 p.p.m. Cu (wet basis). The 2,500 p.p.m. Cu figure, for 5 per cent dry solids sludge, shows that 50,000 p.p.m. Cu (dry solids basis) was present in the sludge at that time. From data now available, it is readily apparent that with this copper concentration the digesters just could not begin to function properly, which, of course, proved to be the case.

With respect to the 1943 digestion difficulties, one of the important facts established was that digesters which were acclimated to copper-bearing sludges were very seriously affected as the copper concentrations increased. This point is important in that it has been assumed that the greatest source of trouble from copper may be expected in starting new digesters.

Referring to another statement made by the late Prof. C. R. Hoover, in the previously mentioned Connecticut State Water Commission Biennial Report, he stated that "It was found that the nature of the chemical compounds of copper precipitated in the sludge is important in its effect on sludge digestion."

This statement emphasizes the fact that all copper-bearing wastes may not necessarily affect sewage treatment operations in the same manner or be toxic to the same extent. However, it can be definitely stated that copper, as copper hydroxide and hydrated copper sulfate, is toxic to sludge digestion, with both forms of copper being toxic to about the same degree.

When copper is present in sewage, the quantity and form of copper that is removed at the sewage treatment plant to become concentrated in the sludge is the real criterion upon which to base determinations as to what deleterious effects this copper may have on sewage treatment processes.

Finally, from actual digestion experiences it has been determined at Kenosha that copper, when concentrated in sludge in large amounts, does seriously affect sludge digestion. When copper is present in excessive quantities, it can actually put an integral part of the plant—the digesters—out of operating condition entirely.

Under these unsatisfactory digestion conditions, proper sludge treatment and disposal is impossible, and the economies of plant operation are seriously upset, since good digestion is necessary for satisfactory conversion of the sludge into an inoffensive material and to provide an adequate supply of fuel for the gas engine driven sewage pumps and for plant heating purposes. For this reason, at Kenosha, the copper- and oil-bearing wastes, due to the quantity and copper content thereof, are classed as deleterious wastes, which should be excluded from the sewer system unless they receive satisfactory pretreatment by the industry so as to render them non-toxic and amenable to existing sewage treatment processes.

# THE TRANSMISSION OF DISEASE BY SEWAGE*

By Robert Newton Clark

*Chief Public Health Engineer, Tennessee Valley Authority, Chattanooga, Tenn. (Formerly District Sanitary Engineer, New York State Department of Health)*

At the beginning of the year 1903, the Ithaca Water Company was busily engaged in improving its water supply. A construction crew was pushing for early completion of a new dam in Six Mile Creek, which was to furnish reservoir storage capacity and a better intake structure than the old crib just below the dam. Plans were even being considered for a filtration plant to remove the troublesome turbidity which was getting into the system through the existing direct intake.

On January 27, 1903, there was a sudden break in the freezing weather, the temperature rose to about 45° F. and a cold rain started falling which soon reached the proportions of a torrential downpour. The melting snow and the winter's accumulation of debris were washed into the stream, and a small flood developed, inundating the low sections of the city. On January 29 the temperature fell to 26° F. and the "January thaw" was over.

Eight days after the beginning of the thaw, on February 4, the Board of Health met and discussed the sudden alarming rise in the number of typhoid fever cases occurring in the city. The health officer reported on that date that 216 cases of typhoid fever had been reported to him by physicians (1). A few days later, on February 7, he expressed the opinion that the outbreak had passed its peak, and the number of new cases was declining. Events proved him wrong. Before the epidemic was over there were about 1,350 cases of typhoid fever resulting in 85 deaths in the city. Of the entire population, one person in ten was stricken (2).

An investigation was made, of course, to determine the source of the infection. The report of the state epidemiologist, Dr. Soper, lays the blame on an active case of fever, believed to have been typhoid, in a house about 1½ miles above the intake. He reported that body discharges from the patient had been thrown on the ground, and that the sudden rain falling on frozen ground had washed the disease organisms into the stream, and hence into the public water supply.

Dr. E. M. Chamot, who was actively engaged in the examination of the water supply at the time of the epidemic, stated to the author that there were two other possible sources of contamination. Workmen at the dam, although supplied with privies in a safe location, were not always careful to use these facilities, and a carrier might conceivably have contaminated the water. Furthermore, a railroad construction gang was building a culvert across a tributary of Six Mile Creek a short distance above the waterworks crib. The railroad had provided a watertight tank fitted as a latrine, which had been in use for some time. When the storm was over it was found that the tank had been carried by the freshet into Six Mile Creek.

An interesting commentary is made by Dr. Rosenau (3) who points out that a cook, named Mary Mallon, had been employed in the vicinity of the dam at about the time of the outbreak. Mary Mallon is the name of the infamous carrier, "Typhoid Mary," who was known to have been responsible for 6 outbreaks of typhoid fever involving

* Presented at Spring Meeting of the New York State Sewage Works Assn.; Utica, N. Y.; May 24–25, 1946.

51 persons and who was probably responsible for many other cases not traced to her directly.

Still one other point remains to be mentioned. For several months previous to January, 1903, the Ithaca *Daily Journal* carried a monthly summary of reports on the chemical and bacteriological examination of the public water supply. Invariably these reports were unfavorable. On Thursday, January 29, 1903, a boil-water order was published and Prof. G. S. Williams, engineer for the water company, stated for publication that he agreed with the Board of Health warning and that since his residence in Ithaca he had always made it a practice to boil water for his personal use. On February 4, Commissioner Horton, of the Ithaca Board of Health, made a statement that expressed a salient fact: "We cannot go over the city with clubs and compel the people to boil water."

## Sewage Works and Public Health

The foregoing brief summary of a typical water-borne outbreak of typhoid fever illustrates a number of points on disease transmission. This discussion deals, of course, with diseases that are transmitted by sewage, which are mainly those affecting the intestines of man, although some others will be mentioned.

There are three factors to be considered in a study of the transmission of any communicable disease. First is the infective source, such as an active case of disease or a carrier, from which the disease agent is being discharged. Second is the transmission channel by which the organism is carried from one person to another, and third is a susceptible individual to whom the disease agent is delivered. In the Ithaca epidemic, all of these factors were obviously present, including the ten per cent of the population not immune to typhoid fever.

Another point of importance to those engaged in public health work is contained in Commissioner Horton's remark, "We cannot go over the city with clubs and compel people to boil water." The rest of his remark is equally pungent, "but we can compel the company to install a filtering plant." It is a plain fact that individuals cannot be depended upon to protect their own health; to conserve the lives of its people, a community must provide public protection.

Today, the construction and operation of sewage works to provide for safe and unobjectionable disposal of community wastes is common practice, but to achieve the greatest benefit from such works, designing engineers and operators must not become so preoccupied with refinements in operation that they lose sight of the public health. It is well to keep in mind the expression of William Budd, a great pioneer in epidemiology, when he remarked (4) that the sewer is "the direct continuation of the diseased intestine," and treat sewage with the caution it deserves. In the chain from the infected source, through the channel of transmission to the susceptible victim, it is the business of the sewage works designers and operators to sever the connecting link. To do so involves some understanding of diseases which may be carried in sewage.

## Enteric Infections

The group of diseases that come first to mind are the enteric infections. These are typhoid fever, the paratyphoid fevers, bacillary dysentery, cholera, amebic dysentery and the so-called "common diarrheas." These are usually classed as water-borne diseases, but can equally well be designated sewage-borne infections.

### *Typhoid*

Typhoid fever has been waging a losing battle in the United States. The death rates in deaths per 100,000 persons from typhoid and paratyphoid fevers in the United States dropped

from 35.8 in 1900 to 2.8 in 1935 (5). The remaining typhoid is mostly rural. In 1940 a compilation of 78 large cities showed a typhoid death rate of only 0.48 per 100,000. In general, the number of cases of typhoid can be estimated as ten times the death rate.

Typhoid fever is caused by infection with a bacillus, *Eberthella typhosa*, which is discharged with body wastes from active cases or from healthy carriers of the disease. In warm weather the organism will survive in sewage or water for several days, and in cold weather it may survive for several months. Typhoid carriers may continue to discharge the bacillus for many years, even though they bear no other sign of a diseased condition. Raw sewage must be considered as always contaminated with the organisms of typhoid fever.

*Paratyphoid*

There are two parathyphoid fevers, both similar in nature to typhoid, but usually with a somewhat lower death rate. Paratyphoid A is caused by an infection with the bacillus *Salmonella paratyphi*, and paratyphoid B is caused by the bacillus *Salmonella schottmülleri*. It is believed that a large percentage of so-called typhoid fever is really paratyphoid infection, and a surprisingly large proportion of carriers are discharging the paratyphoid bacillus (3). Closely related to the paratyphoid organisms are *Salmonella aertrycke*, *S. enteritidis*, and *S. cholera suis*, which are usually associated with food poisoning.

*Food Poisoning*

Although food poisoning ordinarily results from direct contamination by food handlers, there are many possibilities for contamination of food with sewage. For example, supplies may be stored under leaking soil pipes, water used for dishwashing or for preparation of food may be contaminated with sewage or sewage solids may be spread by insects or rodents. Of the several types of food infections, such as botulism, staphylococcus and *Salmonella*, only the *Salmonella* group is sewage-borne. The causative organism of botulism, *Clostridium botulinum*, is a soil organism not usually associated with sewage, and the staphylococcus organisms are commonly found in pus, as from blackheads, blisters or boils.

*Salmonella* infections of the gastro-intestinal tract are characterized by sudden onset of nausea, vomiting, abdominal pain and diarrhea, occurring usually from 12 to 24 hours after the ingestion of contaminated food. Susceptible individuals may develop symptoms within 8 hours and others may not be affected for as long as 30 hours. Fatal cases are quite rare.

*Salmonella* differs from other types of food poisoning in that it is essentially an infection and not an intoxication. Botulism and staphylococcus poisoning are literally that. The organisms produce a poison in the infected food such that even though the living bacteria are destroyed, the toxin in the food will cause the characteristic symptoms. With *Salmonella*, the living organism must be ingested to cause the disease.

*Cholera*

One of the great epidemic diseases of history is Asiatic cholera. It was during an investigation of a cholera epidemic that John Snow led the way for future epidemiologists to track down water-borne outbreaks, with his classic instance of the Broad Street pump, in London, in 1854.

Today cholera is mainly a tropical disease, and about 98 per cent of the known deaths from this disease occur in India. The disease is caused by infection with *Vibrio cholera*. The source of organisms is almost always an active case, and carrier states are few and short-lived. It is our business to hold cholera at bay in this country.

*Dysenteries*

There are two forms of dysentery, one caused by *Bacillus dysenteriae*, the other caused by the protozoan *Entamoeba histolytica*. The death rate from bacillary dysentery is somewhat higher than from amebic dysentery.

Bacillary dysentery is widespread and the number of reported cases is increasing. Felsen states (6) that the incidence in the United States in 1937 was approximately sixteen times that reported for 1933, but points out that reported cases of unclassified "diarrhea, enteritis and dysentery" have correspondingly declined.

Watt and Hardy (7), in a study of *Shigella* bacilli, of the dysenteriae group, reported an average of 9.1 carriers for each current case. They found that carrier rates varied from 0.1 per cent to 11 per cent of the population, depending upon climate and the level of sanitation. Various types of dysentery are relatively common, and the organisms may remain viable in sewage and water for a considerable period of time.

The common diarrheas are caused by any of a number of enteric organisms, or by toxins, which may be ingested with food or drink, or which may be formed in the body.

## Other Sewage-Borne Diseases

Although the diseases so far mentioned, with the possible exception of food poisoning, are all recognized as water-borne infections, the contamination of water is only one of a number of ways in which sewage may transmit disease.

*Tetanus*

For example, there is tetanus, caused by the organism, *Clostridium tetani*. Virtually all warm blooded animals are susceptible to tetanus, and the disease is found wherever the soil is contaminated by animal or human excreta. The spores of tetanus are very resistant, and are widespread and common. Tanner (8) points out that tetanus has been found on the surface of vegetables irrigated with sewage, but that the bacillus is practically harmless when ingested.

*Parasitic Infections*

Of great interest are the parasites which may be spread by body discharges and by Budd's "continuation of the diseased intestine." Many of these, of course, are usually associated with direct contamination of the ground with feces, but it is perfectly possible for fresh sewage solids to account for the same conditions.

One of the commonest parasites transmitted in feces is the hookworm. Hookworm disease is of considerable public health importance in warm countries but it is seldom found north of the 36th parallel. Hookworm eggs are discharged from infested intestines, and under favorable conditions of soil, moisture and temperature, hatch into small wormlike larvae. The larvae enter the body through the skin, usually between the toes, and by a circuitous route find their way to the intestines.

Hookworm disease is seldom fatal, although it decreases the victim's vigor and so causes an economic loss to the community. Hookworm is best controlled by stopping promiscuous soiling of the ground, and by the wearing of shoes.

Other parasites which may be transmitted in a similar manner are the whip worm and the round worms, some of which, such as *Strongyloides stercoralis*, penetrate into body through the skin; other species find entry by ingestion.

*Fluke Infections*

Of some interest at the moment is the question of fluke infections. Ordinarily fluke diseases are not found in the United States, but the return of military personnel from Pacific areas has introduced sources of infection.

The methods by which flukes find entry to the body vary with the species. Some gain a foothold when ingested, others enter directly through the skin. Typical of the latter are the schistosomes or blood flukes.

The ova of *Schistosoma* are discharged with feces or urine, which upon coming in contact with fresh water hatch into free-swimming *miracidiae*. In this stage they must find a certain species of snail within a few hours time, otherwise they perish. In the snails the organisms undergo further change and emerge finally as fork-tailed *cercariae*, which are capable of penetrating human skin.

Contact of a person's skin with infested water is sufficient to lead to an infection. Fortunately, in this country, the species of snail necessary to the life cycle of *Schistosoma* is not present, and the danger of transmission is not great.

## Hazards in Sludge Utilization

The use of sewage sludge as fertilizer has raised many questions as to the dangers of disease transmission by this means. Although most of the enteric bacilli are sufficiently attenuated or destroyed by storage in a digestion tank for ten days or longer (8), great caution should be used in the application of air dried sludge to growing crops which might be eaten raw.

Infection with amebic dysentery is possible where the cysts have survived treatment. The ova of certain parasites may survive treatment of the sludge, and become infective under favorable conditions.

Under the conditions of sludge handling in many sewage treatment plants, the sludge as actually drawn is not all 10 days old. If sludge additions are made to the tank at daily intervals, it is quite possible for some fresh sludge to be mixed with the digested sludge drawn for disposal. In such an event, even the less resistant bacteria, such as *E. typhosa*, may be present with a consequent hazard to health.

Sludge that is heat dried at high temperatures is considered to be a safe fertilizer for any crop.

## Shellfish Hazards

Another mode of disease transmission by sewage is the infection of shellfish areas. In the winter of 1924–25 cases of typhoid fever began to multiply, first in New York and then in Chicago and Washington, until from the middle of November until the middle of January, these cities had full-scale epidemics. A high incidence of typhoid was noted at the same time in ten other cities (4). All told, fifteen hundred people were infected. The epidemiological study of these outbreaks showed that oysters marketed by a single company were responsible.

The methods by which shellfish can be contaminated are very numerous. The growing beds may be bathed in diluted sewage from a nearby community, or they may be contaminated by the discharge of sewage from the dredges working on the surface above the beds. Great care is necessary in the handling of shellfish, especially shucked oysters and clams, to prevent soiling from hands, working surfaces or polluted wash water.

## Disease Transmission by Flies

Although we do not often think of it in such terms, sewage sometimes takes wing and flies off in all directions. The common house fly has a particular liking for sewage solids and its cosmopolitan appetite, coupled with its restless energy, results in a promiscuous distribution of feces to all points within the flight range of the insect. Draw a circle, with a radius of one mile, around each point where fresh sewage solids are exposed to flies and some idea of the possibilities of infection can be grasped.

Flies spread infectious organisms in three ways, by direct carriage of con-

taminated matter, by regurgitation of infected material, and by defecation. Fortunately, in the United States, the fly appears to be a diminishing public health hazard.

## Bathing Hazards

The indictment against sewage is not yet complete. Consider the hazards of bathing in water polluted with sewage. Not only are bathers vulnerable to agents which cause disease when swallowed, but in some instances simple contact of the body with polluted water is enough to cause infection. There is no clear evidence to show the incidence of eye irritations and middle ear infections arising from exposure to polluted water, but it must be considerable.

Intensive effort has been devoted to drafting standards of purity for bathing water at natural beaches. Such standards usually are based on the numerical density of coliform bacteria, but regardless of the figure stated in the particular standard used, the statement is invariably qualified to prohibit bathing near a sewer outlet. This is in recognition of the extra hazard arising from recent discharge, in distinction to the hazard from inadequate dilution.

## Poliomyelitis

Of even greater popular interest is the possibility that the virus of poliomyelitis may be transmitted in water contaminated with sewage. McClure reported that the polio virus in stools remained infectious after 124 days at a temperature of −5° C. In Charleston, S. C., in 1939, the virus was found in sewage. In Detroit, in 1931, at one institution, 19 polio contacts were examined and 6 were found to be carriers. In one of these, the carrier state persisted for 38 days.

These are isolated facts, and certainly do not prove that the usual mode of transmission of polio is by the sewage route. They do, however, light up the caution signal.

## Conclusion

It is not possible, in a short time, to exhaust the subject of disease transmission by sewage. We are viewing only the mountain ranges, and have not the time to explore the valleys. Nor is it the purpose of this discussion to set forth didactic statements as to what means should be employed to handle sewage so as to render it innocuous.

Let us keep in mind, however, when faced with a sewage treatment problem that it is dangerous to handle the stuff and still more dangerous to turn it loose. Let us remember, too, the individuals who through foolishness, ignorance or helplessness, cannot protect themselves from the hazards in which we deal.

## References


1. Ithaca *Daily Journal*, February 4, 1903.
2. Annual Report, Water Department, Ithaca, New York (1937).
3. Rosenau, Milton J., "Preventive Medicine and Hygiene."
4. Smith, Geddis, "Plague On Us."
5. American Public Health Association, "Water Borne Outbreaks in the United States and Canada, 1930–1936, and Their Significance," Report of the Committee on Water Supply of the American Public Health Association, Annual Year Book, Vol. 20, No. 2.
6. Cecil, Russell L., "Textbook of Medicine."
7. Public Health Reports, United States Public Health Service, March 9, 1945.
8. Tanner, Fred W., "Public Health Significance of Sewage Sludge When Used as Fertilizer," THIS JOURNAL, 7, 4, 611 (1935).

# EFFECTS OF GROUND GARBAGE ON SEWAGE TREATMENT PROCESSES *

By Willem Rudolfs

*Chief, Department of Sanitation, Rutgers University, New Brunswick, N. J.*

The household garbage grinder is unquestionably the most convenient form of garbage disposal from the standpoint of the housewife, but control is entirely beyond the jurisdiction of the sewage works operator. The operator must take care of the material coming to the treatment plant and for that reason the possible effects of garbage grinders on the various treatment units is of interest to him.

## Relative Quantities of Garbage

We find in the literature a number of estimates regarding the quantities of garbage produced. The relation between sewage suspended solids present and the amounts added by garbage is variously estimated. The values given in the literature for garbage production vary from 15 to 200 per cent of the suspended solids in domestic sewage.

Some of the estimated increases in percentages of solids when all garbage is mixed with sewage are as follows:

| Author | Per Cent Increase |
|---|---|
| Cohn (1) | 21 |
| Carpenter (2) | 21 |
| Babbitt (3) | 21 |
| Calvert (4) | 16 |
| Tolman (5) | 17.5 |
| Lauster (6) | 91 |
| Engineers' Handbook | 22 |

Offhand, it would seem that most of these estimates are rather low. If we consider that fine screens remove from 8 to 10 per cent of the total suspended solids, nearly all in the form of screenings (including garbage), and occasionally as much as 17 to 18 per cent, it would seem that much of the garbage is already in the sewage.

Records of garbage collection in this country show quantities varying from 0.4 to 2.0 lb. per capita per day, with moisture contents varying from 70 to 90 per cent. On the basis of dry solids the quantities of garbage appear to vary from 0.05 to 0.3 lb. per capita per day. Controlled collections indicate that the amount of dry garbage solids is about equal to the dry solids in domestic sewage.

## Composition of Garbage

A comparison of the principal chemical constituents of garbage and domestic sewage solids shows:

| | Sewage Solids | Garbage |
|---|---|---|
| Volatile matter (%) | 70–80 | 80–90 |
| Ash (%) | 20–30 | 10–20 |
| Grease (%) | 15–35 | 13–33 |
| Nitrogen (%) | 4–6 | 0.4–1.5 |

It will be noted that the percentage of volatile matter in garbage is somewhat higher than in sewage solids, the grease content is about the same, perhaps usually somewhat lower, and the nitrogen content only 1/10 to 1/4 of the nitrogen present in sewage solids. The lower nitrogen content may be of importance in biological treatment processes.

## Effect on Sewers

The newest domestic garbage grinder produces a comparatively finely divided, rather fluffy material. According to Cohn, the volume of water used during grinding may be as little as one gallon per capita per day. In other words, the volume of material

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, N. J. Presented at 31st Annual Meeting, New Jersey Sewage Works Assn.; Trenton, N. J.; March 20–22, 1946.

added to the sewer would perhaps be 1 per cent and not exceed 2 per cent of the total sewage volume. From a volume standpoint, the effect on the sewers would be negligible.

Examination of a sample of ground garbage indicated that, with the small amount of water used, the concentration of the material discharged might be in the neighborhood of 3 per cent total solids. There is no reliable information available to show how this material behaves in a sewer, but since the ground garbage is rather finely divided and fluffy in nature, and since it would be diluted in the sewer with a large volume of water, it may be expected that as a rule no difficulties in sewers with a good grade would be encountered. Information is needed regarding the behavior of ground garbage in flat sewers, siphons and sumps. It is reasonable to expect that whenever settling takes place in sewers without ground garbage, more sludge will settle when ground garbage is present.

## Effect on Grit Chambers

The grit collected at most treatment plants is not particularly free from organic matter, unless special equipment is available. Ground garbage settles fairly rapidly and an increase in the volatile matter may be expected. More organic matter in grit would mean more offensive material. Evaluation of the amount of volatile matter added by ground garbage may be rather difficult, but Calvert (4) found increases from 20 to 40 per cent.

## Effect on Settling

### *Rate of Settling*

Experiments conducted in our laboratory (8) on the rate of settling of ground garbage solids alone and in conjunction with sewage solids showed that ground garbage settled very rapidly. The rapid rate of settling is indicated by a few figures showing the percentage of settleable solids removed when the garbage was mixed with half, equal and twice the amounts of sewage as compared with sewage alone:

| Time (min.) | Per Cent Settleable Solids Removed | | | |
|---|---|---|---|---|
| | Sewage Alone | Garbage:Sewage Ratio of Mixture | | |
| | | 1:2 | 1:1 | 2:1 |
| 1 | 7 | 48 | 55 | 60 |
| 2 | 18 | 53 | 65 | 70 |
| 5 | 33 | 70 | 82 | 90 |

When the ground garbage was mixed with half the volume of sewage, about 70 per cent settleable solids were removed in 2 min. and about 90 per cent in 5 min. The figures indicate that the larger the volume of sewage the slower the rate of settling.

### *Sludge Volume*

The volume of sludge produced will depend primarily upon the assumed quantity of garbage present and the time of compaction. If it is assumed that garbage-sewage sludge compacts at least at the same rate as sewage sludge alone, the volume of sludge produced depends upon the quantity of garbage present. Assuming that the material still contains about 97 per cent water, we may put it differently and say that the volume of 3 per cent sludge produced by household grinding amounts to one gallon per capita per day.

Now let us compare the volume of sludge produced per capita per day from domestic sewage with the one gallon of ground garbage solids. If we take an average domestic sewage with 200 p.p.m. total suspended solids and a water usage of 100 g.c.d., the volume of 3 per cent sludge produced would be 730 gal. per m.g. of sewage, or 0.73 g.c.d.

If we use another method of calculation, namely, the production of 90 grams of suspended solids per capita per day, we find that the total volume

of 3 per cent sludge produced would be 0.79 g.c.d. If we take the estimate of total solids from garbage as about 20 per cent of the total sewage solids, the volume of 3 per cent sludge produced should be about 0.2 g.c.d. On the basis of equal production in the form of garbage and as sewage solids, the solids concentration in the ground garbage would be about 3 per cent. It appears that we may expect an increase in sludge volume amounting to 100 per cent.

*Compaction*

Ground garbage concentrates readily to 8 to 10 per cent solids. When it is mixed with sewage solids, the concentration is practically the same as that of sewage solids alone. Ground garbage may aid in the concentration of sludge. Large scale experiments have shown that no particular difficulties are encountered, provided the garbage-sludge mixtures are not stored too long.

*Removals*

During the grinding of garbage the coarser particles are reduced in size and juices are squeezed out. Most of the suspended particles settle readily and may aid in the removal of finely divided sewage solids. The result is that addition of ground garbage will not greatly affect suspended solids removal. The *percentage* removal may even be higher, but since the total suspended solids in the sewage-garbage mixture is greater, there may be an increase in the total suspended solids in the effluent.

Experiments and experience seem to indicate that ground garbage added to fresh sewage results in poorer effluents; garbage added to stale sewage may have no effect or be slightly beneficial, and when trade wastes are present the garbage may aid in removal of suspended materials.

The effect of garbage addition on B.O.D. removal is much less confusing. In general, there is an increase in the B.O.D. of the effluent when garbage is added. The B.O.D. of the garbage liquor may vary from 3,500 to 12,000 p.p.m. Depending upon the quantity of garbage added, the B.O.D. of the effluent from settling tanks will increase in proportion.

*Scum*

A portion of the ground garbage is fibrous (vegetable) and lighter than water. Some of this material has a tendency to float. The amount of floating material is relatively small, but an increase in scum formation may be expected.

## Chemical Treatment

Experiments (9) to determine the effect of ground garbage on the clarification of sewage and the B.O.D. of effluents when chemicals are used for coagulation show that the addition of garbage causes a greater or smaller removal of suspended solids. The reduction of suspended solids is affected by the character of the sewage, the nature of the garbage and the type of coagulant. Although the suspended solids may not increase, the soluble B.O.D. in the effluent increases.

The addition of ground garbage causes an increase in chemical coagulant, but the increase is not in proportion to the amount of suspended ground garbage added. When lime and ferric chloride are used the additional cost may vary from a few cents to $1 per million gallons, depending upon the amount of garbage present. When lime and alum are used the additional cost is even less. Best results with lime-ferric chloride coagulation appear to occur at pH 9.0 to 9.5, whereas with lime-alum coagulation similar results can be obtained at pH values of 8.5 to 9.0.

Reasonable dosages of ferric chloride or alum do not decrease the "soluble" B.O.D. introduced with the garbage, and therefore the B.O.D. in the effluent will increase in direct relation to

the quantities of garbage liquor added.

The addition of ground garbage causes only a comparatively small increase in chemical cost, but increases the amount of sludge to be handled.

## Effect on Filters

Addition of ground garbage to sewage will usually result in somewhat higher quantities of suspended solids in the effluent from settling tanks; hence, the quantity of suspended solids placed on standard or high rate filters will increase. The increase in suspended solids does not appear to be of great importance if the filters have not reached maximum loading. Naturally, addition of ground garbage will affect overloaded filters in proportion to the increased quantities of suspended solids present in the influent to the filters.

The B.O.D. of the effluent from settling tanks receiving sewage-garbage mixtures may increase from 0 to 35 per cent. Hence, the B.O.D. loading on the filters increases. The increase in total B.O.D. is nearly all caused by the presence of soluble substances pressed out of the garbage during grinding. These soluble substances are readily oxidized and at a slightly higher rate than sewage (10).

The higher B.O.D. will cause no particular difficulties as long as the filters are of sufficient capacity to handle the material. Even if all the garbage were handled by household grinders, the capacity of the filters would increase only about one-third as compared with filters for settled sewage alone.

## Effect on Activated Sludge

Laboratory experiments on the effect of ground garbage on the activated sludge process (10) showed that the rate of oxidation was similar to or greater than the rate of oxidation of substances present in settled sewage. The oxidation progressed as far or farther than the oxidation of sewage alone. There was no interference in the stabilization of the effluents as indicated by nitrate production. The sludge volume did not materially increase and the sludge was not more bulky than from sewage alone.

Plant scale experiments (4), in which the performance of the activated sludge process during a period of garbage grinding was compared with the same period during the previous year, do not indicate that the activated sludge process was improved by the addition of garbage, but there was also no indication that the ground garbage caused disruption of the activated sludge process.

Sludge production appeared to be somewhat higher. The removal of B.O.D. in parts per million and in pounds per 1,000 cu. ft. of air will be practically the same for sewage with ground garbage as for sewage alone (5). The latter method of expressing results would seem to indicate that any additional B.O.D. in the raw sewage caused by the ground garbage would appear in the effluent; hence, a somewhat higher B.O.D. in the effluent if garbage is added. It is also indicated that each pound of garbage B.O.D. requires the same amount of air as that in the sewage, therefore, air requirements are increased. Presumably the same degree of purification can be obtained if the aeration time is longer or the amounts of air are increased.

It is clear that addition of ground garbage will not particularly affect the results produced by the activated sludge process, provided the sewage is settled before aeration.

## Digestion

Early experiments on the digestion of garbage alone (12) indicated that the time required would be materially longer than for sewage solids or mixtures of garbage and sewage solids, probably because of the small amount of nitrogen present in garbage. Later experiments (2) (3) (6) (11) showed

that digestion of sewage sludge-garbage mixtures was feasible and practicable.

Addition of garbage to digestion tanks directly or in the sewage is not detrimental, but the digestion capacity required increases at least in direct proportion to the quantity of garbage added. To date no favorable effect on the rate of digestion by the addition of garbage has been reported and substantiated. Some years ago the writer made the following statement (13) which is still believed to hold:

"Garbage added continuously is not detrimental, but the digestion capacity required increases in direct proportion to the quantity of volatile matter. Since none of the results indicate a more rapid digestion of the garbage or garbage-fresh solids mixtures, and no more total gas was produced (per pound volatile matter) from these mixtures than from the control, it may be assumed that under these conditions each pound of volatile garbage solids required the same digestion time as each pound of volatile matter in the fresh (sewage) solids. Consequently, when 100 per cent garbage is added (on the basis of fresh solids) the tanks must be at least twice as large."

The degree of fineness of the garbage particles is a factor in the rate of digestion. Finer material digests somewhat more rapidly and is better distributed throughout the sludge than coarsely ground garbage.

The theoretical quantity of gas to be expected from garbage is in proportion to the volatile solids. Experiments (2) (3) (6) (11) show that the amounts and composition of the gas produced from mixtures of garbage and sewage solids are about the same as from sewage solids alone on an equal volatile solids basis. The quantity of gas from plain sedimentation solids varies from 6 to 9 cu. ft. per pound dry solids, depending upon the volatile matter content. The amount of gas per pound volatile matter which may be expected under operation conditions varies from 8 to 12 cu. ft.

Early plant scale experiments with additions of garbage to separate digestion tanks showed that a considerable portion of the material had a tendency to float and was difficult to keep submerged. Later practice has indicated that excessive scum formation may be avoided by thorough mixing, recirculation of supernatant liquor or dilution with sewage. These methods will work, provided the digesters are not worked to capacity or, worse, overloaded.

The presence of garbage in Imhoff tanks is somewhat more difficult, because recirculation or submergence of the scum by floating covers is not practiced. Additional hosing may temporarily reduce the amount of scum. No matter what type of digestion tank is used, greater vigilance is required to prevent troubles if garbage is added.

## Sludge Disposal

The quantity of sludge produced when ground garbage is added will always be greater than if sewage alone is handled, and the volume of sludge to be dried on sand beds increases. Unfortunately, in many instances the sludge drying bed area available is barely enough or insufficient for sewage sludge alone.

Investigations on the chemical dewatering of sludge produced from ground garbage-sewage sludge mixtures show that the material can be readily dewatered with the aid of ferric chloride and lime or ferric chloride alone (14) either before or after digestion. The percentage increase of chemicals required per ton of dry solids is about the same as the percentage increase in garbage solids. In other words, if the solids increase 50 per cent by the addition of garbage, the chemical demand also increases about 50 per cent.

Soluble and finely divided organic material produced by the grinding of garbage has a considerable chemical demand. When garbage is added to the sewage these soluble substances are

washed out and less chemicals are required.

The filter cake produced from either settled garbage-sewage sludge mixtures or digested garbage-sewage sludge has practically the same moisture content as sludges without garbage when the same amounts of chemicals are added to the same solids concentration.

## Chlorination

The soluble organic substances and finely divided material pressed out by grinding of garbage have a high chlorine demand. These substances are not removed by settling; hence, the chlorine required increases in proportion to the garbage juice added. This increase is, however, not doubled if the amounts of suspended solids in the form of garbage are doubled.

With 100 per cent garbage added the chlorine demand of the effluent from the settled mixture increases by 20 to 50 per cent. Putting it differently, a settled sewage with a chlorine demand of 10 p.p.m. will increase to about 15 p.p.m. if ground garbage is added. A stale sewage with a chlorine demand of, say, 20 p.p.m. will increase to about 25 p.p.m. when garbage is added. The chlorine demand of a garbage-sewage mixture effluent from a chemical treatment plant is only slightly increased.

## Conclusions

Addition of ground garbage to the sewer system may necessitate more flushing and cleaning, and sewage treatment facilities must be increased. The difficulties caused by the introduction of ground garbage are not insurmountable, but existing sewage treatment plants, particularly those which are loaded to capacity or are already beset with troubles, can expect more difficulties. Increased difficulties may be an incentive to improvements and expansion of the plants.

The additional cost of handling ground garbage does not seem exorbitant, although the cost of handling water-carried garbage may be greater than with the present methods. New sewage treatment plants should be constructed on the basis of addition of ground garbage, with particular attention paid to grit chambers, scum removal, digestion capacities and sludge dewatering facilities.

It is the writer's belief that the use of household garbage grinders will gradually increase. Recently he expressed the opinion "that ordinances prohibiting the installation of household garbage grinders will not have much more value than many existing ordinances forbidding connections of cellars and roofleaders to sewers. Ordinances may temporarily retard the number of installations, but if general economic conditions warrant the installation, the pressure through advertising and real estate brokers will be so great that gradual installation will proceed."

## References


1. Cohn, M. M., "The Combined Collection and Disposal of Sewage and Food Wastes." THIS JOURNAL, **7**, 43 (1935).
2. Carpenter, L. V., A. C. Rogel, and B. Grabois, "The Disposal of Garbage in the Sewerage System." THIS JOURNAL, **8**, 728 (1936).
3. Babbitt, H. E., B. J. Leland, and F. H. Whitley, Jr., "The Biologic Digestion of Garbage with Sewage Sludge." *Bull.* 287, Eng. Exp. Station, Univ. of Ill. (1936).
4. Calvert, C. K., and S. L. Tolman, "The Effect of Ground Garbage on Sewage Treatment Plant Operation." *Water Wks. & Sew.*, **83**, 161 (1936).
5. Tolman, S. L., "Combined Treatment of Garbage and Sewage. Where Does it Stand?" *Munic. Sanit.*, **8**, 313 (1937).
6. Keefer, C. E., and H. Kratz, "The Quantity of Garbage That Can be Digested with Sewage Sludge." THIS JOURNAL, **6**, 250 (1934).
7. Lauster, K. C., "Disposal of Garbage with Sewage." *Pub. Wks.*, **71**, 25 (1940).

8. Ingols, R. S., "Effect of Garbage on Settling of Sewage." *Proc.*, 22nd Annual Meeting, N. J. Sew. Wks. Assoc., p. 60 (1937).
9. Rudolfs, W., and R. S. Ingols, "Chemical Coagulation of Sewage. VII. Effect of Garbage." THIS JOURNAL, **9**, 406 (1937).
10. Rudolfs, W., and R. S. Ingols, "Effect of Ground Garbage on Oxidation." *Munic. Sanit.*, **8**, 356 (1937).
11. Malcolm, W. L., "Studies in the Digestion of Ground Garbage." THIS JOURNAL, **9**, 387 (1937).
12. Rudolfs, W., and H. Heukelekian, "Digestion of Vegetable Wastes and Screenings in Sewage Treatment." *Water Wks. & Sew.*, **67**, 113 (1928).
13. Rudolfs, W., discussion of paper "Studies in the Digestion of Ground Garbage." THIS JOURNAL, **9**, 651 (1937).
14. Rudolfs, W., and R. S. Ingols, "Effect of Garbage Upon the Dewatering of Sludge." *Munic. Sanit.*, **9**, 172 (1938).

V.
19

# SEWAGE TREATMENT AT AN AFRICAN NATIVE COMMUNITY

By R. S. Young, A. J. Hall and A. W. Darvall

*Chief Research Chemist, Microscopist, and Sectional Engineer, Respectively, Rhokana Corporation Limited, Nkana, Northern Rhodesia*

The large base metal companies in Northern Rhodesia operate their own water and sewage works, serving not only the plants but also the European townships and native compounds. Several years ago Rhokana Corporation at Nkana, Northern Rhodesia, built four Imhoff tanks to receive the sewage from Wusakili Compound, a recently established location for approximately 9,000 natives.

From rather extensive inquiries made by the authors, this appears to be the only instance in Africa where Imhoff tanks are handling exclusively native sewage. In Northern Rhodesia and elsewhere in Africa native compounds have been provided with septic tanks, and Imhoff tank installations apparently are found only where a mixed sewage from Europeans and Africans is handled. It was accordingly felt that some observations on the effect of native diet on the composition of sewage and operation of Imhoff tanks would be of interest to sanitary chemists and engineers.

The Wusakili Imhoff tanks do not receive any industrial wastes or sewage from the European township, but solely that from latrines in the compound together with all water from washing slabs and showers. Storm water and surface runoff from the compound do not enter the sewage system, so that variations in flow are confined to those normally encountered in domestic sewage. Latrines are flushed by automatic tip tanks holding 20 gal., and the rate of tipping is maintained at approximately once every 15 to 20 min. Since all water at the compound is filtered and chlorinated, as a conservation measure this water is shut off from 9 P.M to 5 A.M. Apart from these, there are no differences between the sewage of Wusakili compound and that of any small non-industrial urban community.

The volume of sewage handled has varied from 372,200 to 423,600 gal. per 24 hours, with an average of 390,000. This gives an average of 43 gal. per capita per day, comparing favorably with the usual figures of 40 gal. in Britain and 80 gal. per day in the United States (2). The mining companies in Northern Rhodesia, unlike the gold mines in South Africa, provide accommodation in their compounds for the wives and families of native employees. The results reported here are accordingly representative of a typical large community of Africans.

## Treatment Facilities

Preceding the Imhoff tanks are trash racks to remove rags, sticks, and other coarse undigestible matter, and sand traps to settle out sand and grit. The removal of the latter was found to be very important in handling native sewage owing to the large quantity of sand used by the women for scouring kitchen utensils, as well as the sand and mineral dust derived from washing the clothes and bodies of those who perform the physical labor in large mining and metallurgical operations.

The four Imhoff tanks follow the usual design for this structure, having a total capacity of 44,600 cu. ft., and a digestion capacity of 9,500 cu. ft. or approximately 1 cu. ft. per capita. At the present time there is no further treatment of the Imhoff tank effluent

and it is simply discharged into a nearby stream. Provision has been made for final treatment of this effluent by percolating filters or similar purifying devices when this step becomes necessary. The sludge from the tanks is pumped periodically to drying beds and is used as a fertilizer on the mine gardens.

## Operation Observations

When the tanks had been in operation a short time excessive foaming occurred. Undigested sludge entraining a lot of gas rose in the gas vents, leaving a small quantity of solids in the bottom of the tanks below a considerable volume of clear liquid. A number of changes in the operation of the tanks were tried over the course of many months to reduce this frothing. The frequency of deshudging was altered over wide ranges without appreciable differences in foaming tendencies. Continuous mechanical removal of sludge from gas vents and breaking up the foam with compressed air and water jets were tried with no success.

One of the tanks was given a continuous lime addition to promote flocculation and keep the settling compartment free of froth overflowing from the gas vents. When a preliminary dosage of 50 to 100 lb. $Ca(OH)_2$ per 24 hours had no effect, the addition was increased to 300 lb. per day which raised the pH from approximately 7 to over 9. The limed tank soon became entirely free of froth. There was practically no difference in suspended solids, B.O.D., and bacterial numbers between the effluents of the limed and unlimed tanks. The latter continued to be covered with a layer of froth slowly rising from the gas vents.

The similarity in the effluents in spite of the difference in the surface appearance of the tanks was probably due to a counterbalancing effect of retarded biological activities at the high pH against the greater coagulation induced by lime. The result was that foaming was eliminated, but the quality of the effluent was little changed by this lime treatment. The sludge from the limed tank was smaller in bulk, slightly darker in color, and appeared to dry more rapidly than the sludge from unlimed tanks. Owing to the favorable conditions for fly breeding prevailing throughout the year in Northern Rhodesia it is important that rapid drying of the sludge occurs on the beds.

If we had been concerned with further purification of the Imhoff tank effluent, probably a smaller lime addition to give a slightly lower pH would have been advantageous. This would have increased biological activity while retaining much of the flocculating action brought about by the lime. Since we were not concerned with reduction in B.O.D. or bacterial numbers as long as the suspended solids were low enough to discharge the effluent directly into a stream, the lime treatment was eventually discontinued as an unnecessary item of labor and expense.

## Character of Sewage

The population of Wusakili compound is composed of approximately 3,000 men, 3,000 women, and 3,000

**TABLE 1. Weekly Ration for Africans in Wusakili Compound**

| | Man | Woman | Child |
|---|---|---|---|
| Mealie meal | 10.5 lb. | 5 lb. | 5 lb. |
| Mealies, whole | | 5 lb. | |
| Meat, beef | 1 lb. | — | |
| Meat, offal | | 1 lb. | |
| Bread | 2 lb. 10 oz. | — | |
| Beans | 1 lb. | 8 oz. | |
| Soybeans | 5 oz. | | |
| Peanuts | 1 lb. | | |
| Vegetables, green | 2–3 lb. | | |
| Tomato juice | 8 oz. | | |
| Fruit, fresh | 2–3 lb | | |
| Salt | 5 oz. | | |
| Dripping | 5 oz. | | |
| Sugar | 1 lb. 3 oz. | | |
| Honey | 4 oz. | | |

**TABLE 2.—Analytical Data on Sewage from Wusakili Compound**

| | Raw Sewage | Imhoff Tank Effluent | Digested Sludge |
|---|---|---|---|
| Suspended solids (p.p.m.) | 215 | 98 | — |
| Volatile suspended solids (p.p.m.) | — | 97.9 | — |
| Ash of solids (%) | 21.44 | — | 52.35 |
| Biochemical oxygen demand (p.p.m.) | 200 | 120 | — |
| pH | 7.2 | 6.5 | — |
| *B. coli*, present in | 1/1,000,000 ml. | 1/100,000 ml. | — |
| absent in | — | 1/1,000,000 ml. | — |
| Total organisms, per ml. | 500,000–1,000,000 | 370,000–570,000 | — |
| Nitrogen in solids (%) | 2.93 | — | 2.55 |
| Carbon in solids (%) | 21.34 | — | 11.53 |
| Grease in solids (%) | 9.10 | — | 4.01 |

children. The basic food of the native is mealie meal, i.e. corn meal, approximately 96 mesh, and this is issued at the rate of 10.5 lb. per man per week, 5 lb. per woman, and 5 lb. per child. In addition the natives receive a variety of other food stuffs, as shown in Table 1.

The above is typical of the rations supplied by the Company compound and has been found to be well-balanced and ample in quantity for the average individual and family. The native, of course, is quite at liberty to, and frequently does, purchase additional food from time to time. In addition, a number of families augment their ration from small garden plots in the area surrounding the compound. On the whole, however, this table represents the typical diet of the African in Wusakili compound.

The analytical data for the raw sewage, Imhoff tank effluent, and digested sludge are given in Table 2. The determinations were carried out using standard procedures (1). Chloroform was employed as the solvent for grease.

From the above analytical data and other information obtained during the operation of these tanks exclusively on native sewage it is possible to calculate a number of variables in terms of grams per capita. These are given in Table 3.

The suspended solids in the raw sewage and Imhoff tank effluent are about normal for sewage works serving a European population. Practically the entire content of suspended solids in the Imhoff tank effluent is organic in nature, and it is therefore apparent that settlement of the heavier inorganic particles is excellent.

Ash of the suspended solids is only slightly lower than the average for domestic sewage. There is a tendency for Africans to include more of the coarser portions of vegetables, fruits, and meats in their diet, and they are less fastidious in removing dust and dirt from foodstuffs than are Europeans. Both these factors would tend to raise the ash content of sewage.

**TABLE 3.—Amount and Nature of Raw Sewage and Digested Sludge from Wusakili Compound**

| | Solids (gm./cap./day) | | |
|---|---|---|---|
| | Mineral | Organic | Total |
| Raw Sewage: | | | |
| Suspended solids | 9 | 33 | 42 |
| Settleable | — | — | 23 |
| Non-Settleable | 0 | 19 | 19 |
| Nitrogen | — | — | 1.23 |
| Carbon | — | — | 8.96 |
| Grease | — | — | 3.82 |
| Digested Sludge | 6.28 | 5.72 | 12 |
| Nitrogen | — | — | 0.30 |
| Carbon | — | — | 1.38 |
| Grease | — | — | 0.48 |

On the other hand the ash content of the native's staple article of diet, mealie meal, is somewhat lower than the ash of the more varied foodstuffs used by the white race. The result is a domestic sewage differing only slightly in ash content from that found in other parts of the world.

The ash content of the digested sludge is rather higher than that found for domestic sewage elsewhere. This is probably due chiefly to clay particles which are not settled out in the sand traps. African women generally use a handful of fine sand or clay to scour utensils or even to scrub their hands. The data show that practically none of this inorganic matter goes out in the Imhoff tank effluent, and nearly all is flocculated with the aid of the organic matter in the tanks.

The figures for B.O.D., pH and bacterial numbers are about what one might anticipate from an ordinary domestic sewage. Similarly the nitrogen contents of raw suspended solids and digested sludge do not differ very materially from similar installations elsewhere. The large percentage decrease in carbon content from the solids of raw sewage to digested sludge is a reflection of the high carbohydrate content of the native diet. Grease, soaps, and fats of raw sewage are on the high side, indicating a strong tendency for froth formation.

## Summary

As a result of studies carried out a large African compound in Northern Rhodesia, analytical data are presented on the effect of native diet on the composition of sewage and operation of Imhoff tanks.

## References

1. "Standard Methods for the Examination of Water and Sewage," 8th ed., American Public Health Association, New York (1936).

2. Imhoff, K., and G. M. Fair, "Sewage Treatment," John Wiley & Sons, New York (1940).

# Industrial Wastes

## TREATMENT OF SULFITE WASTE LIQUOR ON HIGH RATE TRICKLING FILTERS*

By Richard G. Tyler, William Maske and Robert Brewer

*Respectively, Professor of Sanitary Engineering, University of Washington, in Charge of Disposal Project, Pulp Mills Research; Associate Research Chemist, Pulp Mills Research; and Assistant Chemist, Pulp Mills Research*

In January, 1944 the pulp and paper mills in the state of Washington entered into a 5-year contract with the University of Washington under which the latter was to organize and carry on research on the utilization and disposal of sulfite waste liquor (hereinafter termed "SWL") and other wastes from the participating mills, who in return would finance the research within the limits mutually agreed upon. The University, through the Dean of the Graduate School, placed an existing Committee on Lignin and Cellulose Research in charge of initiating and directing the program. A technical committee representing the industry advises with the University's committee and serves as a liaison between the mills and the University.

The program is divided into the following three projects:

1. Basic lignin research.
2. Utilization of sulfite waste liquor.
3. Disposal of sulfite waste liquor.

Each of these projects now has its own staff and laboratory and is working on those problems which it selects, with the advice of the above mentioned committees, as most important and immediate. The present paper deals with one phase of the activities of the Disposal Project.

As a first step in initiating research on the disposal of SWL, a brief summary of the known facts about the liquor and its biochemical treatment was compiled. These facts and the reasons why high rate filtration was selected as the first method of disposal to be investigated in the present research can be stated briefly.

1. SWL is an acid waste from the manufacture of wood pulp, having 12 to 13 per cent solids in solution, mostly organic, and lacking in nutrients required for bacteriological growth.

2. Nutrients not present in the SWL must be added for satisfactory growth of micro-organisms. Specifically, the liquor has been assumed by investigators to be a deficient in nitrogen and phosphorous.

3. The activated sludge method has been successfully used on a laboratory scale for treating SWL-sewage mixtures in concentrations not exceeding 10 per cent of concentrated SWL (12,000 to 13,000 p.p.m.).

4. Treatment of SWL on filters has been in progress in Wisconsin but to date results and operating conditions have not been made available.*

5. One of the authors in 1939–40 operated two 6-ft. diameter high rate filters on SWL-sewage mixtures, and later on SWL dilutions to which

* Presented at 1946 Annual Meeting of the Pacific Northwest Sewage Works Assn.; Gearhart, Ore.; May 22, 1946.

* Since the preparation of this paper, the authors have had the opportunity of studying a summary report on the Wisconsin research. See This Journal, **18**, 4, 671 (July, 1946).

ammonia had been added. Among the phenomena studied, along with the biochemical digestion of SWL, were (*a*) methods for handling excessive growths of molds in the filters; (*b*) difficulties encountered in the use of the standard B.O.D. test with SWL; (*c*) problems arising from excessive foaming and (*d*) methods for adjusting the pH of SWL.

## Analysis of the Problem

The liquor contains approximately 10 per cent of volatile (ash-free) solids with 12 to 13 per cent total solids, practically all of which are in solution. The four major components of SWL are the carbohydrates, lignin, several inorganic chemicals and a group of volatile organic compounds. The carbohydrates consist principally of sugars; lignin is the cementitious material in the wood; the inorganic chemicals come from the solvents used for dissolving the lignin and include free and loosely combined $SO_2$; and the volatile organic compounds include alcohol, acetic acid and other by-products of the cooking process. Of these, the most important from the standpoint of this investigation are the carbohydrates, $SO_2$, and the volatile acids.

To utilize the currently accepted methods from the field of sewage treatment in treating the liquor would require prior neutralization to raise the pH from a value of from 1.5–2.5 to a pH of 7.0–7.3. This requires considerable quantities of lime or caustic and would add greatly to the cost of treatment. There is an obvious advantage, therefore in experimenting with disposal methods at a low pH where the addition of lime is unnecessary.

It should be mentioned also that the nitrogen content of the liquor is only about 0.1 per cent on the basis of dry solids. It would appear necessary to add nitrogen (and possibly phosphorous) as nutrients to sustain bacterial growth. In some of the research hitherto done on SWL, added sewage furnished these essential elements. In the present research, where nitrogen has been used it was added as ammonium hydroxide since our previous experience had indicated that the micro-organisms in the filter could utilize ammonia nitrogen.

## The Origin of the B.O.D. of SWL

The necessity for treating sulfite waste liquor arises primarily from its high oxygen demand and the consequent depletion of the dissolved-oxygen content of waters into which it is discharged. No materials toxic to fish life are present in the liquor so far as is known. While the low pH of the liquor may also be objectionable under some conditions, ample dilution by the receiving waters may prevent it from becoming a problem. It is obviously important, however, to find methods for removing much of the oxygen demand exerted by the liquor.

The B.O.D. of SWL originates in its component fractions. One research* in this field divides the responsibility for the 5-day oxygen demand approximately as follows:

TABLE I. Source of B.O.D. of SWL

| Component | Per Cent of Total B.O.D. |
|---|---|
| Immediate chemical demand ($SO_3$) | 11 |
| Sugars | 63 |
| Acetic acid | 12 |
| Alcohols (approximately) | 1 |
| Lignin, furfural, etc. | 13 |

These percentages are in terms of the actual B.O.D. as determined by test rather than of theoretical values. Computations based upon two analyses taken from Benson and Partansky give a much larger importance to lignin as compared with the sugars. Table II gives the computed, or theoretical, B.O.D.'s for the components as determined by these two tests, and may be considered as the maximum

* William R. Barber, Crown Zellerbach Corporation, Camas, Washington.

**TABLE II.—Computed B.O.D. of Sulfite Waste Liquor [1]**

| Component | Sample One | | | | Sample Two | | | | Computed as |
|---|---|---|---|---|---|---|---|---|---|
| | Grams per Liter | Total Solids (%) | Computed B.O.D. | | Grams per Liter | Total Solids (%) | Computed B.O.D. | | |
| | | | P.P.M. | Per Cent of Total B.O.D. | | | P.P.M. | Per Cent of Total B.O.D. | |
| Formic Acid | 0.63 | 0.53 | 218.9 | 0.155 | 1.19 | 0.86 | 413.5 | 0.25 | $HCOOH$ |
| Acetic Acid | 4.68 | 3.95 | 4,990 | 3.36 | 5.22 | 3.77 | 5,560 | 3.38 | $CH_3COOH$ |
| Methyl Alcohol | 1.26 | 1.07 | 1,880 | 1.27 | 0.72 | 0.52 | 1,079 | 0.65 | $CH_3OH$ |
| Ethyl Alcohol | 0.171 | 0.14 | 300.8 | 0.20 | 0.230 | 0.17 | 439.5 | 0.27 | $C_2H_5OH$ |
| Acetone | 0.134 | 0.11 | 295.6 | 0.19 | 0.099 | 0.07 | 218.2 | 0.13 | $CH_3COCH_3$ |
| Furfural | 0.285 | 0.24 | 474.6 | 0.32 | 0.244 | 0.18 | 406.5 | 0.25 | $C_5H_4O_2$ |
| Pentose | 2.55 | 2.16 | 4,246 | 2.86 | 3.37 | 2.43 | 5,610 | 3.41 | $C_5H_{10}O_5$ |
| Hexose | 17.5 | 14.8 | 18,770 | 12.65 | 17.1 | 12.3 | 18,240 | 11.1 | $C_6H_{12}O_6$ |
| Lignin | 61.5 | 52.2 | 117,011 | 78.9 | 69.6 | 50.2 | 132,500 | 80.5 | $C_{45}H_{42}O_{14}$ |
| Misc. | 29.3 | 24.8 | — | — | 40.93 | 29.5 | — | — | |
| Total | 118.0 | 100.0 | 148,186.9 | — | 138.7 | 100.0 | 164,466.7 | — | |

[1] "Methods of Analysis of Sulphite Waste Liquor" by A. M. Partansky and H. K. Benson.

possible demands for these various materials.

The 5-day and even the 20-day B.O.D. depends much more on the chemical demand from $SO_2$ and on the B.O.D. of the carbohydrates than it does on that of lignin. It is essential, therefore, that any acceptable treatment should take care of the maximum possible oxygen demand from $SO_2$ and carbohydrates.

## Selection of a Method of Treatment

The principal oxygen demand of both sewage and SWL arises from carbohydrates. Since trickling filters and the activated sludge process have been the most successful methods employed in handling sewage, it seemed probable that these methods would also prove most satisfactory in treating SWL. In 1939 and 1940, therefore, the senior author started research on the treatment of SWL on a two-stage, high rate trickling filter. In this research, difficulties were encountered with growths of molds in the filters which produced clogging and with B.O.D. problems that appeared easier to study on smaller filter units. When the present research was undertaken, therefore, it was decided to set up a number of small, laboratory-scale, high rate trickling filters so that it would be possible to examine the numerous factors involved in the biochemical treatment of the liquor without entailing too great an expenditure of time and money in making changes found to be necessary as the research proceeded.

Another consideration was involved in the selection of the method of treatment to be used. Again referring to experience in the field of sewage treatment, it has been found that methods of oxidation are more effective, or more rapid, than those of reduction. An examination of a typical B.O.D. curve indicates that aerobic oxidation proceeds at a rate of 20.6 per cent per day at 20° C., while a study of anaerobic processes indicates an average rate of breakdown of about 8.4 per cent of the existing organic matter per day. It was thought advisable to take ad-

vantage of the higher efficiency of aerobic decomposition which would dictate the use of filters or the activated sludge process. The former was selected as it had the further advantages of simplicity of operation and a greater ability to withstand the shock of wide variations in loading.

## Organisms for Seeding the Filters

In starting the treatment of SWL with high rate trickling filters, the first problem encountered was to determine the type of organism to be used in seeding the filters. Work hitherto done with the liquor has been carried out at a pH of 7.0 or thereabouts, so that the organisms normally found in sewage filters could be employed. It has already been mentioned that high rate filters in Wisconsin were being operated at an acid pH but data concerning filter flora, loading, nutrients, and other details of this research had not been published at the time of preparation of this paper. One of the authors, however, was shown the Wisconsin experimental unit by Averill J. Wiley, Acting Co-ordinator. The authors, for reasons of economy, decided to initiate experiments with filters at an acid pH as near that at which the liquor is discharged from the mill as was found practicable. This required the development of organisms that could function at a low pH and utilize the liquor with such added nutrients as might prove necessary. Experiments were therefore started at pH values of 3.0 and 7.0.

For seeding the filters operated at a pH of 7.0, organisms were obtained from a local sewage filter. Since no information was available concerning organisms that would function at a pH of 3.0 in high rate filters, preliminary experiments had to be run for discovering such organisms. There are, of course, many forms of molds and yeasts that live normally at a low pH. Whether these could utilize SWL was not known. Samples of soil were collected from various sources where it was thought organisms having the desired characteristics might be found. One soil sample was obtained where SWL had been percolating through the soil for some years and where it seemed likely that the micro-organisms might have become acclimated to the liquor. A sample of acid soil from a swamp and another containing decaying wood were also utilized.

SWL diluted with 90 per cent water was seeded with these soil samples and aerated until a substantial growth of micro-organisms appeared. This was continued for some time, supplying additional diluted SWL daily. After a sufficient growth of micro-organisms had occurred, several small filters were started by recirculating through them the SWL dilution seeded with these organisms. The filters consisted of $2\frac{1}{4}$-in. diameter Lucite tubes, 5 ft. long, containing a 4-ft. depth of gravel or crushed stone, $\frac{1}{2}$ in. to 1 in. in diameter. It was anticipated that trouble from clogging and consequent ponding would result from using such small media but this was as large as could be used satisfactorily in so small a tube. Phosphorus and some additional nitrogen were added as nutrients.

Ten experimental filters of this type were put in service using various rates of treatment and operating at varying values of pH from 3.0 to 7.0. Later, when the intermediate pH filters showed no particular advantage over those operating at these two limiting values, all were arranged to operate in pairs of one pH 3 and one pH 7 unit, each pair receiving a different dosage. The pH of the effluent was usually slightly lower than that of the influent. After several weeks operation, the filters became seeded sufficiently to warrant starting a regular schedule of tests to determine their effectiveness in digesting the SWL.

Much time was spent in developing feeding and pumping mechanisms suited to the handling of the small quantities of acid materials involved. This was a laborious process which need not be described here and one which has continually undergone evolution from the beginning of this research to the present time. In fact, the major difficulties that have been encountered in the present research have been caused by defects in, and breakdowns of, pumps and their operating devices. Such difficulties have caused irregular treatment of the filters, thus permitting occasional dying out and decomposition of organisms or the clogging of filters with consequent deterioration in the quality of the effluent.

## Description of the Filters

Figure 1 shows the general arrangement of the experimental filters and the operating mechanism. Because of the low pH, metal pumps could not be used unless they were of stainless steel and these were not available in the small capacities required by the size of the filters. Air pumping devices of various kinds were developed, the most satisfactory being the type shown in the sketch.

Since air was being used for recirculating the liquor, it was also passed through the filter for aeration purposes. Later, arrangements were made to by-pass most of the air and pass only a small amount through the filter and thus more closely simulate conditions which might be used in a full scale plant.

Biofilters used for sewage treatment usually do not require artificial aeration if adequate bottom vents are provided, while Aero-filters do require the use of blowers because of the increased volume of sewage that is present in the filter at any given moment. It was assumed that mechanical aeration might be required in the present research because of the greater loadings anticipated. An 8-in. filter, 4 ft. deep, has been in operation for some months without forced aeration, but has experienced occasional difficulties from ponding.

Briefly, the operation of the filter is as follows: SWL to which nutrients have been added is fed from a container A (Figure 1) to a glass settling tank B, through a rubber tube C, closed by a clamp W. A cam is used to open the clamp at desired intervals for a period of a few seconds only so that the tube will flow full and not be subject to the clogging which occurs when an adjustable clamp is used to throttle the flow to the slow rate required.

If the liquor accumulates in the settling tank B, to a point higher than a vertical tube outlet D, it overflows through this tube to the sewer. Another and lower outlet E, from the settling tank, held by a clamp R, and operated by a second cam and the same motor, leads the liquor to a small bottle F, which forms the pump. Air from the compressor is led to this bottle by a tube G, and, while the clamps R are open, escapes through an overflow H into the settling tank so as to intercept any liquor blown out with the air. The lesser head of combined air and liquor in H lets the air escape through it rather than through E. The cam closes clamp R on E whereupon the air forces the liquor from bottle F into the upper end of the filter J. After passing through the filter, the liquor discharges to the settling tank from which it is recirculated as many times as desired by the mechanisms already described. The amount of feed, the rates of flow and, to some extent, the timing of the various operations, are regulated by adjusting screws on the various clamps and by controlling the air used in pumping. The tank A is large enough to contain the daily supply of material fed to the filter. A small glass tube inserted in its dis-

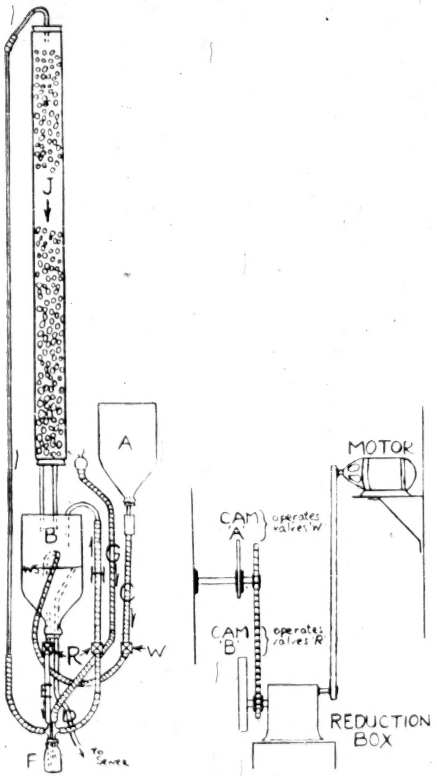


FIGURE 1.—Experimental high rate filter used in sulfite waste liquor studies. Pulp Mills Research, University of Washington, 1944–45.

charge line gives a visible feed if kept only partly filled, so that it is easy to determine whether the equipment is feeding.

This mechanism has been quite successful in its operation though it is subject to interferences from the breaking of clamps, development of leaks in the rubber tubing, clogging of tubes and filters with growths of micro-organisms, and interference with the air supply from various mechanical and power difficulties.

## Control Tests

The tests selected to determine the effects of treatment were those for the B.O.D., sugar, oxygen consumed or permanganate number, and the total and volatile solids. In addition to these, a number of tests for other characteristics in the liquor were made from time to time as the occasion warranted. These included tests for total nitrogen and for lignin, various methods for determining the decrease in volume and consequent

increase in concentration due to evaporation, and bacteriological methods for the identification of micro-organisms found in the filters. Standard methods were used wherever possible with such modifications as were found necessary because of various interfering substances in the liquor.

## Inhibiting Effect of $SO_2$

The inhibiting effects on the filter flora of free $SO_2$ contained in the liquor were recognized at an early stage of this study. It was decided, therefore, that all liquor should be stripped of its free $SO_2$ before being fed to the filters. Several methods of stripping were used, the most successful of which was steam stripping. This process is now in commercial use at alcohol plants utilizing SWL, such as that of the Puget Sound Pulp and Timber Co. at Bellingham, Wash. Here the steam is passed upward through an insulated stainless steel sieve-plate column countercurrent to the controlled flow of SWL. In the laboratory a glass tube filled with Raschig rings and surrounded by a steam jacket was used. The liquor was preheated to minimize its dilution by excessive condensation of the steam. In this process, the free and some of the combined $SO_2$ is removed and may be recovered from the discharging steam. The pH is raised by the removal of $SO_2$ so that, after adding the nutrient, ammonium hydroxide, which raises it further, the pH is 3.8 to 4.0. The low pH filters have been operated at pH 3.8 to 4.0 since steam stripping was begun, *i.e.* since September, 1945.

Another method for removing the $SO_2$ that was used earlier consists of its oxidation using activated carbon as a catalyzer. In this case, preheated SWL was passed downward through a steam jacketed glass tube containing the carbon accompanied by an approximately equal volume of air. A satisfactory rate of treatment was found to be about 140 gal. per cu. ft. of carbon per day. Difficulties from clogging of the carbon with $CaSO_4$ was experienced but a method for preventing this was developed.

In this catalyzer, the free $SO_2$ is oxidized to $SO_3$. This unites with water to produce $H_2SO_4$, which precipitates calcium from the liquor as $CaSO_4$. Precipitation starts in the catalyzer and continues for some hours after discharge therefrom. The pH remains practically constant during this operation (about pH 3 after the nutrients are added) indicating that the precipitation of $CaSO_4$ approximately neutralizes the effect of the increased acidity of the $SO_3$ produced.

The third method of eliminating free $SO_2$ consisted of neutralizing it with ammonium hydroxide. This process was less satisfactory, as measured by filter efficiencies, than the other two. Some investigators who state that it is unnecessary to eliminate the $SO_2$ before submitting the SWL to biochemical treatment adjust the pH with ammonia and lime. The ammonia neutralizes the free $SO_2$ so they actually do remove the $SO_2$ before treatment.

Even the steam stripped liquor develops free $SO_2$ if allowed to stand for any appreciable length of time. There is a gradual change of loosely combined $SO_2$ to free $SO_2$ after the latter has been removed. The quantity thus produced is large enough to interfere with biochemical activities. This action is greatly accelerated by heating. The stripping, therefore, should not precede by too long a time the application of the liquor to the filters or the free $SO_2$ which reappears will interfere with the activity of the micro-organisms.

## Evaporation

The high rate of evaporation which takes place in the filters under the operating conditions employed has caused

considerable difficulty in securing adequate interpretations of the test data. Various methods have been used in trying to correct for this evaporation but its determination is not a simple matter. Since it has sometimes reached 50 per cent of the total volume fed to the filters, and since this amount varies with the amount of foaming occurring in the filters, the volume of air used in pumping and in aerating the filters, and the temperature and humidity of the air, it is obviously important to determine accurately its magnitude and to endeavor to reduce it in so far as possible. To accomplish the latter, the air was for some time bubbled through a column of water so that it would be as nearly saturated as possible before reaching the filters. This cut down the evaporation somewhat but was not a complete solution of the problem and was later abandoned. The increase in concentration was thereafter computed from the ash content on the assumption that this factor would be the same for the effluent as for the influent.

Studies were made of several other methods for determining the amount of evaporation but none of these appeared as satisfactory as the ash determination. Our studies included volumetric measurement of influent and effluent and tests for some fraction of the liquor, such as the lignin, which was assumed to be only slightly changed by filtration. The ash determination, however, was finally, selected as the best method for computing the increased concentration. Preliminary tests indicated that the error caused by the loss of organisms in the effluent, or filtered out of the sample before testing, was less than 5 per cent. This method, therefore, has been used to correct all results for evaporation since September, 1945.

## Procedure

The problems investigated included the effect on B.O.D. and other characteristics of the liquor of (1) pH; (2) temperature; (3) concentration applied to filter; (4) filter loading; (5) recirculation ratios; (6) nutrients added; (7) number of stages; and (8) preparation or pretreatment of the liquor.

The procedure employed consisted of changing a single variable and then operating the filters for two weeks or for such period as was found to be required to reach a condition of stability. Tests were then run and such changes made in operating procedure as appeared warranted from the results obtained. In this way, the various factors affecting the rate of growth of organisms in the filters and the breakdown of the liquor which they produced were determined. The work was complicated by the mechanical difficulties in operation heretofore discussed. By using multiple filters, however, it has been possible to make reasonably satisfactory progress.

## Results

A detailed statement of test data and the various difficulties encountered will not be attempted. Figures 2 and 3, which summarize the results obtained from two extended series of tests, will give a better conception of findings than would more detailed data. Figure 2 shows the percentage and total removal of B.O.D. with varying filter loadings, while Figure 3 gives similar data for the removal of sugars.

The first series covers the period from the beginning of the research to August, 1945, while the second series carries on from that date to the present. The first series represents the earlier work which started with very meager data and mechanisms for feeding and recirculating the liquor. The more frequent clogging of the filters with consequent detriment to effluents, the less efficient methods of stripping the liquor of $SO_2$, and the lesser skill to be expected in meeting new problems of utilizing a new type of filter flora, all

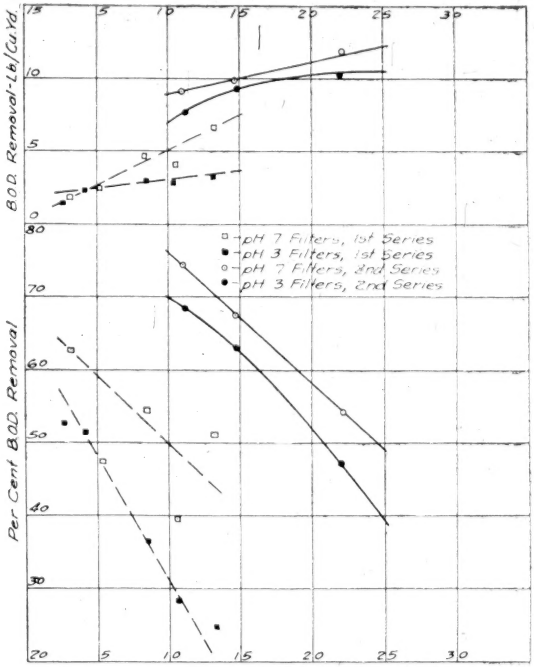
B.O.D. Removal-Lb./Cu.Yd.
Per Cent B.O.D. Removal
pH 7 Filters, 1st Series
pH 3 Filters, 1st Series
pH 7 Filters, 2nd Series
pH 3 Filters, 2nd Series
Filter Loading—Lb. B.O.D. per Cu. Yd. per Day.

FIGURE 2.—Relationship of filter loading to B.O.D. removal.

interfered with the securing of high efficiencies.

The second series began after the pumping and feed mechanisms for the filters had been completely redesigned and rebuilt. Steam stripping was introduced at this time, also, and a correction for evaporation losses rather than attempted reduction of evaporation was practised. The steam stripped liquor has a higher pH (3.8 to 4.0 after addition of nutrients) which is more favorable to yeast growth. Also, the experience gained in the first series made more skillful operation possible in the second. All of these factors explain, in part at least, the higher efficiencies that have been attained in the latter series.

The points shown in Figure 2 represent group averages for 85 separate tests in each series. Each test represented results obtained on an individual filter after operating at a given concentration for a period of two weeks or more. The lines drawn indicate trends rather than statistically accurate averages since the latter would suggest an accuracy not justified by the data because of fairly large individual fluctuations.

The first thing that one notices in studying Figures 2 and 3 is the fact that both the 3.0 and the 7.0 pH filters are doing an extraordinarily good job, especially as to loadings. One needs only remember that for high-rate sewage filters loadings of 2 or 3 lb. B.O.D.

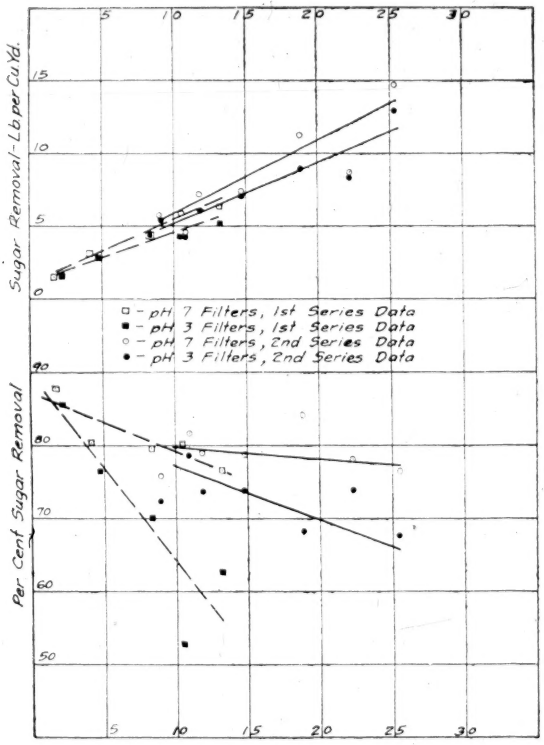
Sugar Removal-Lb per Cu Yd.
Per Cent Sugar Removal
□ - pH 7 Filters, 1st Series Data
■ - pH 3 Filters, 1st Series Data
○ - pH 7 Filters, 2nd Series Data
● - pH 3 Filters, 2nd Series Data
Filter Loading—Lb. B.O.D. per Cu. Yd. per Day.

FIGURE 3.—Relationship of filter loading to sugar removal.

per cu. yd. per day are commonly obtained, with about twice these amounts for strong industrial wastes, to appreciate the effectiveness of the yeasts, molds, and bacteria comprising the flora in these filters. Nor do the curves indicate that the filters have reached their maximum loadings. Further increases in loading are now being applied to the filters. This paper will serve, therefore, as a progress report on the work done to date.

From the graphs it is apparent that the percentage removals of B.O.D. and sugars decrease with increasing filter loading, as would be expected. The pH 7 filters maintain slightly higher efficiencies than do those at pH 3. Greater percentage removals of sugars are produced than of B.O.D. At a loading of 25 lb. B.O.D. per cu. yd. per day sugar removals are nearly 80 per cent while B.O.D. removals approach 50 per cent.

While the percentage removals drop with higher loadings, the total weight of both B.O.D. and sugars removed steadily increases with loading. Here also, the pH 7 filters have a slight advantage over the acid filters. At the maximum loadings attained to date, 14.5 lb. of sugars and 12 lb. B.O.D. per cu. yd. per day have been removed by

individual filters at pH 7.0, while the corresponding removals at pH 3.0 were 13 lb. of sugars and 10 lb. of B.O.D.

## Sugars

Where the term "sugars" is used in this paper, it refers to total reducing substances (by copper) and is used as an abbreviation for the longer designation. The fermentable sugars in stripped or unstripped SWL are approximately 70 to 85 per cent of the total reducing substances, though this is a variable ratio.

The test for sugars has been used in this research because it is quickly and easily made by the modified Folin-Wu clinical test, using a electrophotometer.

**TABLE III. Relationship of Sugar and B.O.D. Removals to Filter Loading**

*1st Series (June 1944 to Aug. 1945)*

| No. of Runs | Filter Loading (lb. B.O.D./ cu.yd.) | Sugar Removal | | No. of Runs | Filter Loading (lb. B.O.D./ cu.yd.) | B.O.D. Removal | |
|---|---|---|---|---|---|---|---|
| | | Per Cent | Lb. per Cu. Yd. | | | Per Cent | Lb. per Cu. Yd. |
| | | | 7.0 pH Filters | | | | |
| 1 | 13.13 | 76.5 | 6.25 | 1 | 13.13 | 51.1 | 6.71 |
| 5 | 10.52 | 80.1 | 5.85 | 3 | 10.52 | 39.6 | 4.17 |
| 8 | 8.33 | 79.5 | 4.35 | 8 | 8.44 | 54.5 | 4.59 |
| 9 | 4.17 | 80.2 | 3.15 | 5 | 5.26 | 47.3 | 2.49 |
| 13 | 1.75 | 87.9 | 1.46 | 7 | 3.13 | 62.7 | 1.80 |
| | | | 3.0 pH Filters | | | | |
| 1 | 13.13 | 62.5 | 5.1 | 1 | 13.13 | 24.7 | 3.25 |
| 4 | 10.52 | 52.7 | 4.35 | 3 | 10.52 | 27.0 | 2.84 |
| 8 | 8.33 | 70 0 | 4.36 | 7 | 8.49 | 36.4 | 2.98 |
| 21 | 4.75 | 76.4 | 2.85 | 22 | 4.14 | 51.6 | 2.35 |
| 15 | 2.16 | 85.7 | 1.53 | 6 | 2.42 | 84.7 | 2.13 |
| | | | *2nd Series (Aug. 1945 to date)* | | | | |
| | | | 7.0 pH Filters | | | | |
| 4 | 8.97 | 75.6 | 5.65 | 2 | 9.25 | 52.5 | 4.91 |
| 7 | 10.85 | 81.7 | 4.48 | 13 | 10.85 | 81.0 | 8.79 |
| 15 | 11.81 | 78.8 | 7.08 | 6 | 11.49 | 62.3 | 7.12 |
| 13 | 14.77 | 78.2 | 7.44 | 6 | 12.05 | 79.7 | 9.60 |
| 2 | 18.22 | 84.0 | 11.14 | 9 | 14.44 | 72.6 | 10.50 |
| 1 | 22.20 | 78.0 | 8.70 | 3 | 15.53 | 51.9 | 8.06 |
| 2 | 25.40 | 76.3 | 14.58 | 1 | 18.45 | 78.7 | 13.05 |
| | | | | 1 | 19.20 | 41.2 | 7.91 |
| | | | | 1 | 22.20 | 52.8 | 11.72 |
| | | | | 2 | 25.40 | 52.9 | 13.43 |
| | | | 3.0 pH Filters | | | | |
| 4 | 8.97 | 72.2 | 5.40 | 1 | 8.93 | 56.8 | 5.07 |
| 10 | 10.85 | 78.5 | 4.35 | 10 | 10.85 | 75.6 | 8.21 |
| 9 | 11.73 | 73.5 | 6.00 | 6 | 11.49 | 62.4 | 7.17 |
| 13 | 14.77 | 73.5 | 7.04 | 6 | 12.15 | 64.3 | 7.82 |
| 2 | 18.82 | 68.0 | 8.97 | 7 | 14.51 | 64.8 | 9.41 |
| 1 | 22.20 | 73.8 | 8.22 | 3 | 15.52 | 58.9 | 9.15 |
| 2 | 25.40 | 67.5 | 12.89 | 1 | 18.45 | 39.6 | 7.31 |
| | | | | 1 | 22.20 | 55.8 | 12.39 |
| | | | | 1 | 25.40 | 44.7 | 11.37 |

and also because it was assumed early in this research that the larger part of the B.O.D. was produced by sugars and free $SO_2$. Since the free $SO_2$ is eliminated by stripping, the sugars remain as the principal source of B.O.D. The sugar test should give an approximate measure of the B.O.D., therefore, and should be a useful test for checking on filter operations more quickly and more easily than with the B.O.D. determination. The test has proven useful for this purpose and has contributed to our understanding of the B.O.D. of SWL.

For example, if sugars are the principal materials to be digested, yeasts are the most effective organisms to use for that purpose. The dying out and decomposition of molds further increase the B.O.D. and, while molds play some part in the digestion of SWL, it is questionable whether their aid outweighs the detrimental effect of their decomposition on the B.O.D. Autolysis of micro-organisms creates a serious problem in the treatment of SWL and it is important either to prevent the growth of the more troublesome organisms in the filters and settling tanks, or endeavor to remove them continuously before septic action sets in. With the use of yeasts, short detention periods help to minimize this factor. In all this, the pH 7 filter does slightly better than those at pH 3 to 4.

The relationship between the removals of sugar and of B.O.D. varies with the filter loading. A removal of 77 per cent of the sugars at a loading of 25 lb. per cu. yd. per day results in a removal of 49 per cent of the B.O.D. as read from Figures 2 and 3. At a loading of 10 lb. B.O.D. per cu. yd. per day the corresponding removals of sugars and B.O.D. are 80 and 76 per cent, respectively. Whether this indicates the possible accomplishment and, at the same time, the probable limitation of laboratory-scale filtration of SWL remains to be more definitely determined by a continuation of the present research.

Another question to be answered is what produces the B.O.D. unaccounted for by the sugars. At the present state of our knowledge of SWL it appears that there is too little breakdown in the lignin to account for the unexplained B.O.D. It seems reasonable, also, to expect that the more volatile fractions of the SWL are removed to a considerable extent by steam stripping along with all of the free and approximately one-half of the loosely combined, $SO_2$. This would leave only the sugars and since these do not account for the total B.O.D., it is possible that partial clogging of the filters may be occurring, accompanied by the death and decay of more than the average number of micro-organisms, resulting in an increased B.O.D. It is obviously important, therefore, to prevent, in so far as possible, autolysis from occurring in the filter, to keep filters flushed out and to prevent septic action in settling tanks.

## Sludge

To date, the sludge problem has been studied only sketchily since in such small laboratory units the unloading of the filter made of small media cannot be expected to indicate what would occur in a full-scale unit with its larger sized rock. The settling compartments have served primarily as pump sumps and were made small enough to prevent the liquor from remaining in them long enough to become septic. However, accumulations of molds and other organic matter appear in the pH 7 settling tanks and require occasional removal. In these, a sludge problem undoubtedly exists. The liquor is dark and cloudy and at times may become septic and odorous.

As for the low pH settling tanks, however, sediment does not accumulate at the lower filter loadings but at higher loadings yeast cells accumulate in the bottom of the tanks. In a full-scale plant, these would doubtless be removed for commercial use. The

liquor is usually quite clear, about the color of tea, and unobjectionable as to odor. At present, an 8-in. diameter filter is in operation which may afford a better opportunity for investigating the sludge problem.

Little attention has been given to detention periods and overflow rates to date since with the higher recirculation ratios used, detention has been a matter of only a very few minutes.

## Tentative Conclusions

Conclusions drawn to date from our research on the high rate filters include the following:

1. Free $SO_2$ and possibly loosely combined $SO_2$ in the SWL inhibits the growth of the micro-organisms in filters and should be removed, preferably by steam stripping, for satisfactory filter operation. Steam stripping, which removes the free $SO_2$ and over half of the loosely combined $SO_2$, increases the pH from 1.5 to about 3.5, a more favorable value for yeast growth.

2. No other inhibiting material has been isolated from the SWL but since the efficiency of treatment decreases with increasing concentrations of the liquor, such inhibitors may be present. For example, molds such as *Penicillium* died out when the concentration of the influent was increased to 40 per cent SWL or more, but developed in abundance at lower concentrations. It is possible that the increased concentration of some substance present in the liquor inhibited continued growth of the mold. It is not the pH that inhibits its growth since the pH was kept constant. This inhibiting condition should not be confused with toxicity; it frequently accompanies increasing concentration of salts in the field of biology. The *Penicillium*, incidentally, eventually accommodates itself to the higher concentration and reappears.

3. pH 7.0 filters are somewhat more effective in removing sugars and B.O.D. but will be more expensive to operate because of the large quantities of lime required for adjusting the pH, and will engender more of a sludge problem than low pH filters.

4. The organisms involved at pH 7 are yeast, molds, and various types of bacteria. At pH 3 to 4, similar yeasts and a few molds are found.

5. The filters are quite sensitive to changes in temperature and the activity of the micro-organisms decreases rapidly at temperatures below 22° or 23° C. At the concentrations indicated by the present tests, sufficient heat is available in the liquor as it comes from the digester to keep the filter at the desired temperature, if adequately housed or insulated.

6. Little additional advantage has been observed when operating at temperatures above 25° C., the temperature at which all of the 1945 research has been carried out, but data for higher temperatures are too meager to warrant definite conclusions. Yeasts should function better at around 30° C.

7. The percentage removal of B.O.D. and sugars decreases while their total weight removed increases with the filter loadings.

8. There appears to be no direct relationship between the removals of oxygen consumed and of B.O.D.

9. High recirculation ratios (up to 100) have been utilized primarily to prevent clogging. Little effect on efficiency, other than from improved operation has been noted.

10. Phosphorus as a nutrient was eliminated early in these experiments with no measurable decrease in efficiency.

11. Two series of runs were made with two-stage operation but with no appreciable effect. The organisms in the first stage filter appear to have done all they were capable of doing and only slight if any improvement occurred in the second stage.

12. The filter influents reached concentrations of 80 per cent SWL (or

total solids of 9.5 to 10.5 per cent) in the second series. Apparently, the filters may be able to take the concentrated liquor since their effluent has had its concentration increased to more than 100 per cent by evaporation. There appears to be some danger of local drying accompanied by hardening to a gummy consistency difficult to remove from the filter.

13. The filter is primarily responsible for the improvement obtained in the SWL as it passes through the plant. The settling tank had to be aerated when made large enough for the usual detention periods, or it became septic. The continuous removal of yeast may eliminate some of this difficulty. In this research, the settling tank served primarily as a pump sump and added little if at all to the efficiency.

14. Small experimental filters for research purposes have the advantage of ease in changing the various factors being investigated, such as pH, concentration and quantity of influent, rates of recirculation, temperature, seeding, etc. They adjust quickly to changes in any of these factors. Among their disadvantages are troubles originating from feeding and recirculating such small quantities of liquor and from excessive evaporation losses. It appears also to be more difficult to secure adequate, natural aeration and to prevent clogging from accumulations of molds or other growths.

15. All B.O.D. removals are computed on the basis of the filter influent which is stripped liquor. Considering the stripper as part of the treatment plant increases the overall removals by about 10 per cent.

16. Several runs of the first series gave B.O.D. removals of 85 to 95 per cent for loadings of 1.5 to 5 lb. per cu. yd. per day. These do not show up in the plotted averages except for a single point of 84.7 (average for six runs) for the pH 3.0 filters on Figure 2. Runs at lower loadings will be repeated with the present more effective apparatus to see whether these high values can be consistently obtained.

# A STUDY OF WASTES FROM THE SYNTHETIC RUBBER INDUSTRY *

By O. R. Placak and C. C. Ruchhoft

*Water and Sanitation Investigations, U. S. Public Health Service, Cincinnati, Ohio*

The rapid creation of the war-inspired synthetic rubber industry intensified the stream pollution problem in the already grossly polluted Ohio River. In addition to their B.O.D. load, these wastes, because of their taste and odor producing properties, present a water processing problem of considerable magnitude. This problem is increased because natural purification reactions are not effective in dilutions of these wastes in streams. These difficulties led to the laboratory study described in this paper.

The material presented is a condensation of more comprehensive data contained in a series of unpublished Public Health Service reports (1). Only typical data are presented here, together with the conclusions derived from them. Most of the discussion of procedures and methods contained in the original reports has necessarily been eliminated.

## Character of Wastes

The more significant characteristics of these wastes, from the pollutional point of view, are shown in Table 1. Butadiene (from alcohol) and styrene manufacture, and copolymer plants are occasionally, though not necessarily, located closely together. The data in Table 1 show the characteristics of the wastes from a complete unit of this type. As shown in the table, these wastes are objectionable because of their B.O.D. contribution and their taste and odor imparting properties. In the case of butadiene waste with a 5-day B.O.D. of 2,500 p.p.m., and recovery and reactor waste with a B.O.D. of approximately 500 p.p.m., the pollutional contribution to a stream will be considerable. It is also evident, from Table 1, that all wastes of any consequence from the synthetic rubber industry will impart disagreeable tastes and odors to water supplies. Even after dilution more than ten times to a total volume of about 120 m.g.d., with condenser water, the odor concentration is 460. In this high dilution, also, 80,659 pounds of B.O.D. having a population equivalent amounting to 474,000 would be produced every 24 hours.

The taste and odor producing properties of these wastes are important and unusual in that they are produced in low concentrations and display an extraordinary persistence. Samples have been held in the laboratory for several months with little diminution in odor, and even under the favorable conditions of the B.O.D. test, such as seeding, maintenance of aerobic conditions with a favorable pH, and temperature, little decrease in odor occurs up to ten days. Some typical results after incubation are shown in Table 2. It is apparent from Table 2 that low concentrations of the various wastes impart considerable odor to river water. It should be remembered also that with these wastes bad tastes are always associated with bad odors. The data given illustrate that there is little odor removal up to ten days under these favorable conditions, in spite of the fact that there is a continuous removal of B.O.D. This latter fact indicates that odor removal and B.O.D. removal do not parallel each other and that the one cannot be used as a measure of the other with these wastes.

* Presented at 19th Annual Meeting, Ohio Conference on Sewage Treatment; Columbus, Ohio; October 31, 1945.

The persistence of these odors is illustrated also by samples collected from several widely separated plants. Facilities for lagooning butadiene waste with the addition of fly ash are available at one plant. Data on these wastes are shown in Table 3. It is estimated that the detention period in the lagoon is about eight days. During this period, the odor concentration is reduced from 8,200 to 4,100.

The following conclusions may be made regarding the characteristics and permanence of these odors:

(1) One of the outstanding characteristics of these wastes is the permanence of their odors, even in very low concentrations and under the conditions most favorable for their biochemical removal.

(2) The odors are not removed from solution at the same rate as B.O.D. and the normal self purification occurring in streams will be of little assistance in removing them. For a considerable time the reduction in odor should be proportional only to the dilution.

(3) The wastes produce odors which are easily recognizable in very low dilutions. Once discharged into a stream they are an important factor in preventing the production of a palatable water for several hundred miles downstream.

(4) Simple lagooning of butadiene waste, with fly ash, does not effect sufficient odor or B.O.D. removal to permit the effluent to be wasted into a stream without deleterious effects.

## Effect on Drinking Water Supplies

The observed effect of tastes and odors on the drinking water supplies in the Ohio Valley during the fall and early winter of 1943-44 was intense and far-reaching. During that period, no filtration plant in a 250-mile stretch of the river was capable of producing a palatable water. It was found at this time that dilutions of rubber wastes in river water gave similar tastes and odors. Consequently, the treatment of dilutions of the wastes for taste and odor removal was investigated, following different methods. Some typical results of these tests are shown in Table 4.

Extensive laboratory experiments on the treatment of dilutions of copolymer, butadiene and styrene wastes in Ohio River water warrant the following general conclusions:

(1) Coagulation alone was of little value in removing the tastes and odors.

(2) Treatment with ozone was valueless, and with water containing styrene wastes was worse than no treatment, as it produced sweet, aldehyde-like odors and undesirable tastes difficult to remove and in some cases having a greater odor intensity than that originally present.

(3) Activated carbon completely re-

TABLE 1.—Analysis of Typical Wastes from the Synthetic Rubber Industry

| Plant Area Involved | Approximate Daily Discharge (m.g.) | pH | Total Solids (p.p.m.) | Suspended Solids (p.p.m.) | 5-Day B.O.D. (p.p.m.) | Odor Concentration |
|---|---|---|---|---|---|---|
| (1) Butadiene Waste | 1.90 | 2.8 | 300 | 27.6 | 2,550 | 16,100 |
| (2) Styrene Waste | 4.62 | 6.2 | 150 | 4.5 | 180 | 690 |
| *Copolymer Plant* | | | | | | |
| (3) Process Waste | 2.34 | 4.3 | 5,580 | 12.3 | 69 | 62 |
| (4) Recovery and Reactor | 0.39 | 8.0 | 570 | 23.6 | 492 | 8,760 |
| (5) Main Sewer | 2.63 | 7.0 | 6,530 | 46.0 | 168 | 930 |
| (6) Main Outfall, Institute | 119.4 | 5.4 | 270 | 15.5 | 81 | 460 |

(5) Represents the mixture of (3) and (4).
(6) Represents the mixture of (1), (2) and (5) plus large quantities of condenser water.

**TABLE 2.—The Survival of Various Odors when Seeded and Incubated at 20° C. and with Dissolved Oxygen Always Present**

| Days Incubated at 20° C. | Ohio River Water at Cincinnati, Ohio (pH 6.9) | | | Copolymer Recovery and Reactor (pH 6.5) | | Butadiene Waste (pH 6.7) | | Raw Styrene (pH 6.9) | |
|---|---|---|---|---|---|---|---|---|---|
| | Concentration 100% | | | Conc. 0.5% | | Conc. 0.3% | | Conc. 0.0125% | |
| | Odor Conc. | Dissolved Oxygen (p.p.m.) | B.O.D. (p.p.m.) | Odor Conc. | Dissolved Oxygen (p.p.m.) | Odor Conc. | Dissolved Oxygen (p.p.m.) | Odor Conc. | Dissolved Oxygen (p.p.m.) |
| 0 | 8 | 10.19 | — | 32 | 8.96 | 16 | 8.79 | 2,000 | 8.60 |
| 1 | 8 | 9.37 | 0.82 | — | — | 16 | 8.21 | 4,100 | 8.04 |
| 2 | 8 | 8.89 | 1.30 | 64 | 7.97 | 16 | 5.30 | 4,100 | 8.52 |
| 3 | 8 | 8.20 | 1.99 | 64 | 5.67 | 16 | 4.92 | 2,000 | 8.21 |
| 4 | 8 | 7.94 | 2.25 | 64 | 5.20 | — | — | 2,000 | 7.80 |
| 5 | — | — | — | 16 | 5.21 | 8 | 2.89 | 2,000 | 7.08 |
| 6 | 8 | 6.50 | 3.69 | 16 | 4.86 | 32 | 2.31 | — | — |
| 7 | 8 | 6.46 | 3.73 | 8 | 4.91 | 16 | 1.43 | 2,000 | 7.42 |
| 8 | 8 | 6.46 | 3.73 | 16 | 4.90 | 16 | 1.20 | 2,000 | 8.33 |
| 9 | 8 | 5.40 | 4.79 | 32 | 4.35 | 16 | 1.22 | 2,000 | 5.82 |
| 10 | 16 | 5.80 | 4.39 | 8 | 4.46 | 16 | 0.82 | 2,000 | 7.11 |
| 11 | 8 | 5.15 | 5.04 | — | — | — | — | — | — |
| 12 | — | — | — | — | — | — | — | — | — |
| 13 | 8 | 4.63 | 5.56 | — | — | — | — | — | — |
| 14 | 8 | 3.55 | 6.64 | — | — | — | — | — | — |
| 15 | 8 | 4.16 | 6.03 | — | — | — | — | — | — |
| 16 | 32 | 2.87 | 7.32 | — | — | — | — | — | — |

moved the tastes and odors, provided sufficient amounts of carbon were used. Even in low waste concentrations, large doses (100 p.p.m. or more of carbon) were required. As most water treatment plants are not equipped to handle and add more than 5 to 10 p.p.m. of activated carbon, it should be appreciated that the requirement of 100 p.p.m. or more involves difficult problems of capacity and cost.

(4) Breakpoint chlorination gave variable results and would require careful control. The best results were obtained directly at the breakpoint; and maintaining this condition in practice seems impracticable at present. Above certain limiting concentrations amounting to 0.50 to 0.90 per cent for styrene waste and 3.0 per cent for butadiene waste, breakpoint chlorination was entirely valueless. The use of breakpoint treatment also depended upon proper contact time. There was a decided tendency, particularly with styrene waste, for the tastes and odors to become intensified after 24 hours of contact with chlorine as compared with those noticeable after two hours' contact. This is probably similar to the reaction with ozone, but the reaction occurs at a slower rate.

(5) Aeration by diffused air appeared to be a promising procedure and even at ordinary temperatures usually produced some odor removal.

**TABLE 3.—Analyses of Wastes (Catch Samples) from a Typical Plant Practicing Lagooning**

| Determination | Butadiene Effluent to Lagoon After Neutralization | Lagoon Effluent After Approximately 8 Days' Detention |
|---|---|---|
| Odor pO Value | 13 | 12 |
| Odor Threshold | 8,200 | 4,100 |
| Color* | 25 | 35 |
| Turbidity | 115 | 75 |
| pH | 5.8 | 5.3 |
| Oxygen Consumed (p.p.m.) | 760 | 611 |
| 5-Day B.O.D. (p.p.m.) | 2,440 | 2,383 |

* Determined on the supernatant.

**TABLE 4.—The Effect of Various Treatment Procedures on Dilutions of Rubber Wastes**

| Treatment Used | 0.6% Butadiene Waste | | | 4.7% Butadiene Waste | | | 0.45% Styrene Waste | | | 1.2% Copolymer Main Sewer | | | 1.2% Copolymer Recovery and Reactor Waste | | | 2.9% Copolymer Process Waste | | | 25% Main Outfall | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste | Initial Odor | Final Odor | Taste |
| Coagulation | 16 | 8 | | | | | 8 | 4 | | | | | 8 | 8 | | 32 | 32 | | 32 | 32 | |
| Ozonation (1 hour) | 16 | 8 | | | | | 8 | 4 | | | | | 8 | 4 | | 32 | 16 | | 32 | 8 | |
| Activated Carbon (1 hour): | | | | | | | | | | | | | | | | | | | | | |
| 10 p.p.m. | 16 | 8 | | | | | | | | 32 | 2 | | 8 | 2 | | 32 | 16 | | 32 | 8 | |
| 20 p.p.m. | 16 | 4 | | | | | 8 | 2 | | 32 | none | | 8 | 2 | | 32 | 8 | | 32 | 4 | |
| 50 p.p.m. | 16 | 2 | | | | | | | | 32 | none | | 8 | none | | 32 | 2 | | 32 | 1 | |
| 100 p.p.m. | 16 | none | | | | | 8 | none* | | 32 | none | | 8 | none | | 32 | none | | 32 | none | |
| 200 p.p.m. | — | — | — | 131,000 | 256 | bad | | | | | | | | | | | | | | | |
| 250 p.p.m. | — | — | — | 131,000 | 64 | bad | | | | | | | | | | | | | | | |
| 300 p.p.m. | — | — | — | 131,000 | 16 | fair | | | | | | | | | | | | | | | |
| 350 p.p.m. | — | — | — | 131,000 | 8 | fair | | | | | | | | | | | | | | | |
| Aeration (1 hour): | | | | | | | | | | | | | | | | | | | | | |
| At 20° to 25° C. | 16 | 8 | — | 131,000 | 4,100 | — | 8 | 2 | | 32 | 2 | | 8 | 8 | — | 32 | 32 | | 32 | 16 | — |
| At 50° C. | 16 | 1 | — | 131,000 | 8 | fair | 8 | 2 | | | | | 8 | none | — | 32 | none | | 32 | 0 | good |
| Breakpoint Chlorination: | | | | | | | | | | | | | | | | | | | | | |
| At 2-hour Breakpoint | 16 | — | slight | 131,000 | — | bad | 8 | — | good | 32 | none | — | 8 | — | slight | 32 | — | fair | 32 | — | bad |
| At 24-hour Breakpoint | 16 | — | fair | 131,000 | — | bad | 8 | — | bad | 32 | none | — | 8 | — | slight | 32 | — | fair | 32 | — | fair |

* Aerated for one hour with 100 p.p.m. of carbon.

Note: More complete data are contained in a mimeographed Public Health Service report: I. A Study of the Purification of Ohio River Water Containing Wastes from the Synthetic Rubber Industry.

When the solution temperature was raised during aeration even so moderately as to 50° C. it was a very effective method of treatment. This temperature raising requirement, however, would be impractical in a water filtration plant.

It is evident from the results of the preceding experiments that a logical solution of the problem should begin with waste treatment before release into streams.

## Methods of Treating Wastes

Various methods of rendering the wastes less noxious were studied. In these studies only the clear wastes with the oily material removed were used. It has been presumed that the heavy, oily material forming a portion of the butadiene waste would be skimmed off at the source as a matter of course and burned or otherwise disposed of.

### *Aeration*

A simple treatment applicable directly to the waste is aeration at raised temperatures, which in these experiments were fixed arbitrarily at 50° C. Aeration at this temperature reduced odor concentrations from 2,000–4,000 to 200. Aeration at higher temperatures, even at boiling temperatures, might be used and would probably aid in odor removal. This procedure would tend to coalesce oily materials and facilitate their removal by skimming. Dilutions of wastes treated in this way were found to be more amenable to the production of a palatable water by ordinary filtration plant techniques.

Aeration might also be accomplished by spraying. In our studies we were able to attain pressures only up to 10 p.s.i. At higher pressures and with recirculation, more favorable results might be obtained, as shown by the work at Nitro (2). Our data (Table 5) indicate that spray aeration under the conditions of these experiments was less effective than diffused air aeration, and that both aeration methods were less useful with styrene wastes than with butadiene wastes.

**TABLE 5.—Effect of Spray Aeration on Butadiene and Styrene Wastes and Dilutions of Those Materials**

| Material and Concentration Used (%) | Temperature of Treatment (° C.) | Odor Concentration | | |
|---|---|---|---|---|
| | | Initial | After Bubble Aeration | After Spray Aeration |
| Butadiene Waste: | | | | |
| 100 | 24 | 1200 | 100 | 250 |
| 1* | 25.5 | 64 | | 16 |
| 1* | 50 | 64 | | 16 |
| 1 | 50 | 16 | | 8 |
| 1 | 50 | 8 | 1 | 8 |
| 2 | 24 | 32 | | 8 |
| 1 | 50 | 2 | None | 2 |
| 1 | 24 | 4 | | 4 |
| 1 | 50 | 8 | | 4 |
| 1* | 50 | 16 | | 8 |
| 1* | 24 | 16 | | 8 |
| 0.5 | 24 | 8 | | 4 |
| Styrene Waste: | | | | |
| 100 | 24 | 600 | 500 | 600 |
| 1 | 24 | 64 | 4 | 16 |
| 1 | 24 | 16 | | 4 |
| 0.5 | 50 | 8 | | 2 |

* Duplicates except for temperature of treatment.

### *Chlorination*

Chlorination might also be used to pretreat these wastes. Experiments on the chlorination of butadiene waste have shown the effluents from such treatment to be colorless and greatly clarified, and concentrations much higher than are possible with the original waste can be successfully treated by ordinary water plant procedures. Because the 24-hour chlorine demand varies from approximately 260 p.p.m. on the filtered waste to 450 p.p.m. with raw waste, considerable quantities of chlorine would be necessary.

### *Sulfur Compounds*

The treatment of styrene and butadiene wastes with sulfur compounds was investigated. Contact with sulfites

or sulfides causes odor reduction in the wastes. Such treatment is particularly useful with styrene waste, and if the reaction time is sufficiently prolonged, an almost odorless waste results. The reaction with either waste is slow and would require about eight days for maximum odor reduction with styrene waste and twice that time with butadiene waste. It is obvious that this type of treatment, unless the reaction rate could be accelerated, would be useful only in those places where lagooning is practiced.

The effects of treatment with 100, 250 and 500 p.p.m. of sodium sulfite and sodium sulfide are shown in Table 6. From the data thus presented it is evident that odor reduction does occur, although this treatment was more effective with styrene than with butadiene wastes. With the former, odor reductions from 1,000 to 4 resulted in eight days, and with the latter reductions were from 4,100 to 250 in seventeen days.

*Activated Sludge*

Previously mentioned procedures for treating rubber wastes are valuable mainly for odor removal. A more complete and desirable treatment would also reduce the biochemical oxygen demand. In any complete treatment of the wastes, therefore, a method or methods should be devised to account for a reduction of organic content and a reduction of taste and odor, two effects which do not necessarily occur simultaneously at the same rate.

Preliminary experiments on the treatment of the wastes by the conventional activated sludge process, as shown in Tables 7 and 8, indicated that a 90 per cent B.O.D. reduction could be obtained only under the following conditions:

(1) That the aeration period be increased to about 24 hours.

(2) That no more than 25 per cent of butadiene and/or styrene waste be fed with a normal domestic sewage.

TABLE 6.—Odor Concentrations Obtained in the Time Indicated after Treating Butadiene and Styrene Wastes with $Na_2SO_3$ and $Na_2S$

| Days Treated | Treated with $Na_2SO_3$ | | | Treated with $Na_2S$ | | |
|---|---|---|---|---|---|---|
| | 100 p.p.m. | 250 p.p.m. | 500 p.p.m. | 100 p.p.m. | 250 p.p.m. | 500 p.p.m. |
| | Butadiene Waste—Original Odor 4,100 | | | | | |
| 1 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| 3 | 4,100 | 4,100 | 4,100 | 8,200 | 8,200 | 8,200 |
| 4 | 4,100 | 4,100 | 4,100 | 4,100 | 8,200 | 8,200 |
| 5 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| 6 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| 7 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| 10 | 1,000 | 2,000 | 2,000 | 4,100 | 4,100 | 4,100 |
| 13 | 500 | 1,000 | 1,000 | 2,000 | 2,000 | 2,000 |
| 17 | 250 | 250 | 250 | 500 | 500 | 500 |
| | Styrene Waste—Original Odor 1,000 | | | | | |
| 1 | 128 | 64 | 64 | 64 | 6 | 128 |
| 2 | 64 | 32 | 32 | 32 | 32 | 64 |
| 3 | 32 | 32 | 32 | 32 | 32 | 32 |
| 5 | 16 | 16 | 16 | 8 | 16 | 32 |
| 6 | 16 | 16 | 16 | 8 | 8 | 16 |
| 7 | 8 | 16 | 16 | 8 | 8 | 8 |
| 8 | 4 | 16 | 8 | 4 | 4 | 8 |
| 9 | 4 | 8 | 8 | 4 | 4 | 4 |

**TABLE 7.—Effect of Feeding Butadiene and Styrene Wastes to Activated Sludge**

| Concentration of Waste (%) | Feed | Initial | | | 4-Hour Effluent | | 24-Hour Effluent | |
|---|---|---|---|---|---|---|---|---|
| | | pH | Suspended Solids (p.p.m.) | Calculated B.O.D. (p.p.m.) | B.O.D. (p.p.m.) | Reduction (%) | B.O.D. (p.p.m.) | Reduction (%) |
| 3.0 (Neutralized Waste) | Control | 7.7 | 2,364 | 320.0 | 27.2 | 92 | 10.7 | 96 |
| | Butadiene | 7.7 | 2,196 | 371.1 | 40.3 | 91 | 13.6 | 96 |
| | Styrene | 7.7 | 2,244 | 310.0 | 47.4 | 85 | 12.2 | 96 |
| 6.0 (Neutralized Waste) | Control | 7.5 | 2,176 | 167.2 | 50.8 | 70 | 12.9 | 92 |
| | Butadiene | 7.7 | 2,276 | 269.7 | 53.1 | 81 | 12.4 | 95 |
| | Styrene | 7.4 | 2,176 | 161.3 | 69.1 | 57 | 9.5 | 94 |
| 12.0 (Neutralized Waste) | Control | 7.1 | 1,828 | 185.3 | 59.2 | 68 | 13.1 | 93 |
| | Butadiene | 7.7 | 2,128 | 405.3 | 131.4 | 67 | 20 | 95 |
| | Styrene | 7.1 | 1,940 | 168.4 | 95.6 | 43 | 8.8 | 95 |
| 24.0 (Neutralized Waste) | Control | 7.1 | 1,712 | 167.4 | 53.5 | 68 | 17.8 | 89 |
| | Butadiene | 7.7 | 2,080 | 674.7 | 412.5 | 39 | 53.8 | 92 |
| | Styrene | 7.3 | 1,668 | 187.1 | 146.8 | 22 | 15.6 | 92 |
| 0.0 (Samples Fed with Fresh Filtered Sewage Only) | Control exp. | 7.7 | 1,720 | 301.7 | 108.1 | 64 | 6.7 | 98 |
| | Butadiene exp. | 8.5 | 2,384 | 307.6 | 72.8 | 76 | 9.5 | 97 |
| | Styrene exp. | 7.7 | 1,672 | 301.2 | 91.9 | 70 | 6.3 | 98 |
| 0.0 (Samples Fed with Fresh Filtered Sewage Only) | Control exp. | 7.5 | 1,696 | 151.7 | 69.5 | 54 | 11.8 | 92 |
| | Butadiene exp. | 8.4 | 2,416 | 152.6 | 78.4 | 49 | 6.7 | 96 |
| | Styrene exp. | 7.5 | 1,748 | 151.5 | 93.8 | 38 | 7.5 | 95 |
| 3.0 (Unneutralized Waste) | Control | 7.3 | 1,644 | 189.3 | 45.0 | 76 | 15.5 | 92 |
| | Butadiene | 6.6 | 2,320 | 259.2 | 26.7 | 90 | 5.7 | 98 |
| | Styrene | 7.1 | 1,716 | 195.1 | 44.6 | 77 | 11.2 | 94 |
| 6.0 (Unneutralized Waste) | Control | 6.9 | 1,492 | 71.2 | 27.9 | 61 | 25.3 | 65 |
| | Butadiene | 4.7 | 2,244 | 220.6 | 29.7 | 86 | 11.2 | 95 |
| | Styrene | 6.7 | 1,576 | 93.8 | 35.0 | 37 | 16.2 | 83 |

(3) That the sludge solids be maintained in the aeration mixture preferably above 2,000 p.p.m.

These experiments showed definitely that the treatment of higher ratios of these wastes with sewage in activated sludge would fail simply because of a lack of sufficient nitrogen and phosphorus and other necessary mineral constituents in the wastes rather than because of any directly adverse effect on the sludge.

### Biological Treatment of Composite Waste

These studies led to the belief that if the stronger wastes could be segregated and composited, a smaller and better balanced waste with respect to minerals would be obtained, which could be more easily and conveniently treated. When this composite waste was introduced into an activated sludge system the results shown in Table 9 were obtained.

The system operates at higher than normal pH values, with a possible maximum of 9.0. This is true in every case in which butadiene is introduced into a biological system and this maximum rise in pH occurs some time previous to the fifth hour. No indication that these higher pH values were harmful nor that they might not be continued indefinitely was detectable. The effluent from this treatment was turbid

**TABLE 8.—Data on Activated Sludge Development Using Butadiene Waste**

| Treatment Received | Days of Operation | pH (Mean Values) | | Biochemical Oxygen Demand—Mean Values | | | Max. and Min. Percentage Removed | | Suspended Solids in Aeration Mixture—Mean Values | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial | 24-Hr. | Initial (p.p.m.) | 24-Hr. (p.p.m.) | Per Cent Removed | Maximum | Minimum | Initial (p.p.m.) | 24-Hr. (p.p.m.) |
| Exp. 1-A | 9 | 8.6 | 9.1 | 2,472 | 1,607 | 35 | 43.4 | 24.8 | 571 | 684 |
| Exp. 1-B | 4 | 8.6 | 9.2 | 2,672 | 1,428 | 46.6 | 63.8 | 21.0 | 712 | 924 |
| Exp. 1-C | 21 | 7.4 | 9.0 | 1,902 | 804 | 57.8 | 92.1 | 21.8 | 1,966 | 3,018 |
| Exp. 2-D | 9 | 9.3 | 9.5 | 917 | 401 | 56.3 | 79.3 | 17.9 | 600 | 515 |
| Exp. 2-E | 19 | 8.7 | 9.3 | 497 | 347 | 30.2 | 86.6 | 7.4 | 2,348 | 2,391 |

Exp. 1-A; No additional materials were added to the substrate.
Exp. 1-B; 50 p.p.m. $(NH_4)_2SO_4$ were added with each feeding.
Exp. 1-C; 50 p.p.m. $(NH_4)_2SO_4$; 148 p.p.m. $CaCl_2$; 133 p.p.m. $MgSO_4 \cdot 7H_2O$; 0.45 p.p.m. $FeCl_3 \cdot 6H_2O$; and 5 ml. phosphate buffer were added with each feeding.
Exp. 2-D; 100 p.p.m. peptone were added with each feeding.
Exp. 2-E; $CaCl_2$, $MgSO_4$, $FeCl_3$ and buffer were added as above.

at first but clarified after several days. The B.O.D. removal amounted to about 80 per cent in 5 hours and 95 per cent in 24 hours. A slight but not excessive tendency toward increased sludge production was noticeable.

The possibility of treating composite waste by means of a trickling filter was also investigated on a laboratory scale. These data are shown in Table 10. The experimental trickling filter used was developed by feeding with settled sewage. On this feed, the average filter efficiency was 78.5 per cent over an 8-day period. A mixture of equal parts of sewage and waste and also straight undiluted waste was fed to the filter for a period of 72 hours for the former and 31 hours for the latter. The length of these filter runs was determined by the amount of waste available. Rate of application to the filter varied from 0.59 to 2.56 m.g. per acre per day. The average percentage of B.O.D. removal for the sewage waste dilution was 90 per cent and for the undiluted waste was 86 per cent. The odor, based on the results of samples run at the 24-hour interval, was reduced from 750 to 16.

**TABLE 9. Treatment of Composite Waste by Activated Sludge**

| Date | Initial pH | | Initial Suspended Solids (p.p.m.) | | Initial 30 Minutes Settleable Solids (ml. per liter) | | 5-Day B.O.D. (p.p.m.) Initial | | 5 Hours | | 24 Hours | | Per Cent B.O.D. Removed 5 Hours | | 24 Hours | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 Hours | | 0 Hours | | | | | | | | | | | | | |
| | C | W | C | W | C | W | C | W | C | W | C | W | C | W | C | W |
| 8/16 | 6.8 | 6.9 | 4,642 | 4,402 | 215 | 365 | 413 | 403 | 80 | 270 | 8.4 | 50 | 92.7 | 33.1 | 98.0 | 87.6 |
| 17 | 6.9 | 7.5 | 2,640 | 2,648 | 120 | 250 | 200 | 420 | 40 | 45 | 8.1 | 8 | 80.3 | 89.3 | 95.9 | 98.1 |
| 18 | 7.1 | 7.8 | 2,402 | 2,503 | 105 | 200 | 156 | 473 | 36 | 126 | 10.9 | 23 | 76.9 | 73.4 | 93.0 | 95.2 |
| 19 | 6.9 | 7.7 | 2,288 | 2,474 | 100 | 250 | 238 | 393 | 33 | 108 | 4.1 | 28 | 86.6 | 72.5 | 98.3 | 92.9 |
| 21 | 6.9 | 7.7 | 2,190 | 2,280 | 100 | 200 | 308 | 466 | 59 | 52 | 6.9 | 25 | 81.0 | 88.8 | 97.8 | 95.2 |
| 22 | 7.1 | 7.7 | 2,238 | 2,648 | 90 | 200 | 149 | 393 | 24 | 49 | 5.1 | 13.5 | 83.8 | 87.5 | 96.6 | 96.6 |
| 23 | 7.5 | 7.6 | 2,116 | 2,158 | 90 | 170 | 379 | 473 | 40 | 51 | 6.7 | 19 | 89.6 | 89.3 | 98.2 | 95.9 |
| 24 | 7.1 | 7.5 | 1,996 | 2,120 | 80 | 170 | 175 | 373 | 31 | 44 | 15.3 | 16.6 | 82.3 | 88.2 | 91.3 | 95.9 |
| 25 | 7.1 | 7.7 | 1,814 | 2,004 | 75 | 130 | 219 | 393 | 27 | 88 | 14.1 | 25 | 87.8 | 75.9 | 93.6 | 93.2 |
| 26 | 7.5 | 7.3 | 1,824 | 2,100 | 80 | 125 | 163 | 418 | 33 | 57 | 10.3 | 8.1 | 79.8 | 86.5 | 97.3 | 98.1 |
| 28 | 7.3 | 7.9 | 1,914 | 2,420 | 80 | 120 | 417 | 376 | 72 | 125 | 11.9 | 17.1 | 82.7 | 66.8 | 97.1 | 95.5 |
| Average | 7.1 | 7.5 | 2,279 | 2,523 | 103 | 198 | 256 | 412 | 39 | 92 | 9.3 | 21.2 | 84.4 | 77.4 | 96.1 | 94.9 |

C—Control fed with sewage only. W—Waste (composite).

**TABLE 10.—Treatment of Composite Waste by the Use of an Experimental Trickling Filter**

| Feed Applied to Filter | Total Time Fed, (hours) | Total Amount Applied (liters) | Equivalent M.G.A.D. During Interval | pH | | 5-Day B.O.D. (p.p.m.) | | Per Cent B.O.D. Removed |
|---|---|---|---|---|---|---|---|---|
| | | | | Influent | Effluent | Influent | Effluent | |
| 50% Composite Waste and 50% Sewage | 0 | 0 | 0 | 6.3 | | 340 | | |
| | 16.5 | 14.0 | 1.49 | 6.9 | 7.8 | 340.5 | 25.3 | 92.6 |
| | 20.0 | 16.0 | 1.01 | 6.9 | 7.7 | 404 | 18.2 | 95.5 |
| | 23.0 | 18.0 | 1.16 | 6.9 | 7.8 | 398 | 39.6 | 90.1 |
| | 39.5 | 42.0 | 2.56 | 6.7 | 7.9 | 359 | 35.2 | 90.2 |
| | 12.5 | 13.0 | 0.59 | 6.9 | 7.8 | 252 | 28.8 | 88.6 |
| | 15.5 | 14.0 | 0.59 | 6.9 | 7.7 | 136 | 16.2 | 89.4 |
| | 68.0 | 58.0 | 1.10 | 6.9 | 7.7 | 195 | 32.5 | 83.3 |
| | 72.0 | 60.0 | 0.88 | | 7.7 | 230 | 19.3 | 91.6 |
| Fresh Sewage Only | 24 | | 1.0 | 7.4 | 7.5 | 292 | 205.5 | 29.6 |
| | 48 | | 1.0 | 7.7 | 7.5 | 189 | 26.9 | 85.8 |
| | 72 | | 1.0 | 7.7 | 7.6 | 263* | 34.5 | 86.9 |
| 100% Neutralized Composite Waste | 2 | | | 7.3 | 7.9 | 328 | 72 | 78.0 |
| | 5 | | | 7.2 | 7.9 | 392 | 35 | 91.1 |
| | 7 | 4.0 | 1.01 | 7.3 | 8.4 | 385 | 71.2 | 78.9 |
| | 24 | 15.0 | 0.81 | 7.4 | 8.3 | 445 | 35 | 92.1 |
| | 31 | 18.0 | 0.99 | 7.4 | 8.4 | 184 | 43.8 | 91.0 |

* 4-Day B.O.D.

The previous experiments had indicated a very real possibility for treating composite waste by biological processes. In these experiments, however, the starting points were healthy cultures (activated sludge or trickling filter) which had been altered by repeated feedings of waste. In the vicinity of rubber plants these might not be available; hence it was necessary to determine whether an active sludge can be produced from the waste alone, and if so, whether it will alter the waste in such a manner as to reduce both the odor and the biochemical oxygen demand. To determine the feasibility of this procedure, a series of aeration experiments was carried out. These experiments were designated as Series 5, A, B, C and D, and are described below:

*Series 5:* These tests were made to study the effect of aeration on neutralized composite waste operated on a 24-hour feeding cycle and seeded initially with raw sewage.

*Series A:* These tests were similar to Series 5 but were operated on a 48-hour feeding cycle.

*Series B:* The effect of aeration on an unneutralized composite waste seeded initially with raw sewage and operated on a 48-hour cycle was evaluated in this series.

*Series C:* This series shows the effect of aeration on a neutralized, unseeded composite waste.

*Series D:* In this series of tests the waste was aerated without neutralization or seeding.

Both Series C and Series D were fed every 24 hours. Unneutralized wastes have a pH of approximately 3.7. This was increased to 6.2 in the neutralized wastes. Seeding was accomplished initially by adding an equal part of filtered raw sewage to the original aeration mixture. Subsequent feeding was accomplished in all series of tests by replacing 50 per cent of the volume of the aeration mixture after a 1-hour settling period with composite waste, at the appropriate time interval.

The aeration experiments were then

**TABLE 11.—Development of Active Sludges for Treatment of Composite Waste (Room Temperature Experiments)**

| Initial Seeding Condition | Neutralized | | | | | | Unneutralized | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seeded Initially | | | | Unseeded | | Seeded Initially | | | Unseeded | |
| Feeding Cycle | Twice Daily | 24 Hours | | 48 Hours | | 24 Hours | Twice Daily | 48 Hours | | Twice Daily | 24 Hours |
| Additional Seed (Raw Sewage) Added With Feed | 0.5% R.S.* | None | 0.5% R.S. | None | 0.5% R.S. | None | 0.5% R.S. | None | 0.5% R.S. | None | None |
| Series No. | A | 5 | 5 | A | A | C | C | B | B | B | D | D |
| No. of Days Operated | 9 | 20 | 21 | 13 | 13 | 16 | 22 | 10 | 15 | 14 | 10 | 27 |
| Ave. Suspended Solids (p.p.m.) | 820 | 550 | 830 | — | 946 | — | 331 | 765 | — | 610 | 479 | 359 |
| Ave. pH | 8.5 | 8.6 | 8.5 | 8.7 | 8.6 | 8.5 | 8.5 | 6.2 | 7.3 | 7.1 | 6.4 | 6.0 |
| Ave. pO of effluent | 1.5 | 2.3 | 2.1 | 3 | 2 | 2.5 | 2 | 1.9 | 3 | 1.2 | 3.4 | 3.4 |
| Ave. effluent turbidity | 19 | 101 | 47 | 5 | 12 | 83 | — | 15 | 32 | 18 | — | 108 |
| Ave. 5-day B.O.D.: | | | | | | | | | | | | |
| Influent | 487 | 498 | 609 | 523 | 691 | 518 | 609 | 483 | 451 | 413 | 485 | 423 |
| Effluent | 199 | 158 | 126 | 37.8 | 51 | 128 | 166 | 51 | 18 | 28 | 61 | 113 |
| Per Cent Removed | 59.1 | 68.3 | 79.4 | 92.8 | 92.6 | 75.3 | 72.8 | 89.4 | 95.9 | 93.3 | 87.4 | 73.3 |

* R.S. denotes Raw Sewage.

continued with Series 5, A, B and C, receiving additionally 0.5 per cent raw sewage with each feeding. Series D was not seeded in this or subsequent experiments. After a reasonable interval with this treatment, the effect of twice daily feedings was tried. Series A, B and D were selected for this and aeration periods of 5 and 17 hours resulted. All of the preceding data were obtained at room temperature and are shown in Table 11.

To determine the effect of temperature, the five bottles were held at temperatures ranging from 2 to 12° C. and aerated. The results are summarized in Table 12. The aeration conditions studied are varied enough to give a reasonable basis for predicting the effect of this type of treatment.

The data obtained showed the possibilities of treatment of composite waste by aeration and continuous feeding, and led to the following conclusions:

(1) Aeration with continuous feeding, irrespective of neutralization and seeding, will act to reduce odor and B.O.D.

(2) Prolonged aeration will build up a floc of biological material, strictly limited in variety, under all conditions tried. This "activated sludge" is probably mainly responsible for B.O.D. removal and its effectiveness depends on the quantity of the predominant organisms developed, which in turn depend on pH and seeding.

(3) The length of the feeding cycle influences the results obtained. In general, longer cycles give better effluents with respect to B.O.D. removal. It also appears to be better to treat unneutralized wastes.

(4) Aeration at low temperatures drastically reduces the B.O.D. removal. Odor removal was affected for the duration of the experiment to a lesser degree. At these low temperatures the effects obtained may be due to aeration alone. Since the butadiene wastes are very hot and constitute about 20 per cent of the volume of the combined waste, reasonable temperatures for treatment by aeration should be obtainable throughout the year.

(5) Higher temperatures with aeration would favor odor removal, but temperatures above 40 to 45° C. could limit the growth of organisms and reduce B.O.D. removal.

(6) Further work on aerobic biological treatment can best be carried out on a pilot plant scale.

## Summary

A condensation of more comprehensive unpublished reports on the char-

**TABLE 12.—Development of Active Sludges for Treatment of Composite Waste (Experiments at 2 to 12° C.)**

| Initial Seeding Conditions | Neutralized | Unneutralized | |
|---|---|---|---|
| | Seeded Initially | Unseeded | Seeded Initially |
| Feeding Cycle | 24 hours | 24 hours | 24 hours |
| Additional Seed (Raw Sewage) added With Feed | 0.5% raw sewage | None | 0.5% raw sewage |
| Series No. | 5, A, C | D | B |
| No. of Days Operated | 8* | 8 | 8 |
| Average Suspended Solids (p.p.m.) | 287.5 | 251.0 | 191.5 |
| Average pH | 7.7 | 4.5 | 4.4 |
| Average Temperature ° C. | 5.0 | 5.0 | 5.0 |
| Average pO of Effluent | 2.4 | 4.0 | 3.0 |
| Average 5-Day B.O.D. | | | |
| Influent | 467.5 | 436.8 | 436.8 |
| Effluent | 349.1 | 204.4 | 220.5 |
| Per Cent Removed | 25.3 | 53.2 | 49.5 |

* 3 similar samples operated for 8 days and averaged.

acteristics and treatment of wastes from the synthetic rubber industry is presented. In general, only typical data and significant conclusions are given, lengthy discussions of procedure having been deleted. The following facts concerning these wastes are demonstrated:

(1) These wastes are objectionable because of B.O.D. contribution and odor imparting qualities. A typical unit comprising butadiene and styrene manufacture and copolymer plants would discharge 120 m.g.d. of waste having an odor concentration of 460 and containing 80,600 lb. of 5-day B.O.D. equal to a population equivalent of 474,000.

(2) An outstanding characteristic of these odors is their resistance to natural purification under the most favorable conditions for their biochemical removal. Laboratory studies demonstrated that little removal occurred in ten days using dilutions of these wastes. This implies that reduction in odor in a stream for a considerable period will be proportional mainly to dilution, and, as actually did occur in the Ohio, will create a very difficult water processing problem.

(3) Using the various treatment procedures available to water purification plants on dilutions of these wastes, the following results with respect to taste and odor removal were indicated. Coagulation was of little value. Ozone treatment accomplished little and in the case of styrene waste altered the odor to make it more objectionable. Activated carbon completely removed the odor, if sufficient activated carbon was used. This may require the use of 100 p.p.m. or more. Breakpoint chlorination is effective if the impractical condition of maintaining the treatment directly at the breakpoint can be accomplished. Above certain limits (0.50 to 0.90 per cent for styrene waste and 3 per cent for butadiene waste) the above treatment was valueless. Its effectiveness also decreased with chlorine contact time.

(4) Procedures for treating the wastes directly before disposal into streams were investigated. The following procedures are valuable mainly for odor removal: (*a*) Aeration at raised temperatures, 50° C. or more, will reduce odors. (*b*) With undiluted butadiene wastes at these temperatures and using bubble aeration, odors of 2,000 to 4,000, depending on the waste, can be reduced to about 200. With un-

diluted styrene waste, little reduction in odor occurs. (*c*) Spray aeration up to 10 p.s.i. pressure was less useful but might be more effective with higher pressures and recirculation. (*d*) Chlorination tended to produce effluents more easily treated for palatable water production but would consume large quantities of chlorine, as the chlorine demand of butadiene wastes is 260 to 450 p.p.m. (*e*) Treatment with $Na_2SO_3$ or $Na_2S$ was very effective with undiluted styrene waste (less so with butadiene waste) but required at least a 5- to 8-day detention period. With styrene waste odor reduction in eight days was from 1,000 to 4; in the same period no reduction occurred with butadiene waste, but in seventeen days the reduction was from 4,100 to 250.

(5) Investigations were made to determine methods of reducing the B.O.D. simultaneously with odor removal. The data show that these wastes are not necessarily toxic to a biological system, such as activated sludge, but that separate treatment will fail because of lack of nitrogen and phosphorus and possibly other mineral constituents. Treating wastes separately by means of activated sludge to obtain a 90 per cent B.O.D. removal can only be accomplished by increasing the aeration time to about 24 hours, maintaining sludge solids above 2,000 p.p.m. and feeding no more than 25 per cent butadiene and/or styrene waste with good domestic sewage.

(6) The investigations also showed that compositing the stronger wastes produced a waste better balanced with respect to minerals which would, when introduced into an activated sludge system, give an 80 per cent B.O.D. removal in 5 hours, and 95 per cent removal in 24 hours. This composite waste when used in an experimental trickling filter at rates varying from 0.59 to 2.56 m.g.a.d. had a mean B.O.D. removal rate of 86 per cent for undiluted waste and 90 per cent when mixed with an equal volume of sewage.

(7) Finally, data are presented to demonstrate that a biological floc can be induced in this composite waste by aeration, using minimum amounts or no sewage for seeding. The variety of organisms is limited but, contingent on conditions of neutralization, seeding and aeration time, will reduce the B.O.D. 60 to 95 per cent and produce effluents having odors of the order of 4 to 8. Low temperatures (2° to 12° C.) affect the B.O.D. removal drastically, but since butadiene wastes are very hot this should be controllable.

## References


1. (a) Ruchhoft, C. C., O. R. Placak, and Francis I. Norris, "A Study of Treatment Procedures for Taste and Odor Removal in Ohio River Water." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, September, 1944.
   (b) Placak, O. R., C. C. Ruchhoft, and Francis I. Norris, "Studies of Synthetic Rubber Wastes, I.—A Study of the Purification of Ohio River Water Containing Wastes from the Synthetic Rubber Industry." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, February, 1945.
   (c) Placak, O. R., and C. C. Ruchhoft, "The Influence of a Tributary Draining a Highly Industrialized Area on Tastes and Odors in the Ohio River." Memorandum; U. S. P. H. S., Water and Sanitation Investigations, December, 1944.
   (d) Placak, O. R., A. L. Holman, and C. C. Ruchhoft, "A Memorandum on the Survival of Odors and Tastes in Dilutions of Wastes from the Synthetic Rubber Industry and in Ohio River Water." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, February 5, 1945.
   (e) Placak, O. R., A. L. Holman, and C. C. Ruchhoft, "A Study of the Effect of Treatment of Ohio River Water at Aurora, Indiana." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, January, 1945.
   (f) Terhoeven, G. E., "Synthetic Rubber Wastes Summary. A Study of Buna

S Type Synthetic Rubber and Allied Wastes in the Charleston, W. Va., and Louisville, Kentucky, Areas." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, January, 1945.

(g) Moore, W. Allan, "A Progress Report on the Wastes Produced in the Manufacture of GR-S Synthetic Rubber at Institute, W. Va." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations.

(h) Placak, O. R., C. C. Ruchhoft, and James F. Pierce, "Studies of Synthetic Rubber Wastes, II.—Experiments on the Treatment of Butadiene Waste and Styrene Waste by Activated Sludge." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, February, 1945.

(i) Placak, O. R., and C. C. Ruchhoft, "Studies of Synthetic Rubber Wastes, III.—Experiments of Composite Wastes by Biological Procedures." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, April 30, 1945.

(j) Placak, O. R., and C. C. Ruchhoft, "Studies of Synthetic Rubber Wastes, IV.—The Development of An Active Sludge for the Treatment of Composite Waste." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, May 9, 1945.

(k) Placak, O. R., J. F. Pierce, and C. C. Ruchhoft, "Memorandum on an Analytical Study of Wastes from the Butadiene and Styrene Plant, at Kobuta, Pa." Mimeographed Report, U. S. P. H. S., Water and Sanitation Investigations, April, 1945.

2. Haynes, Lawson, and Wallace Grant, "Experiments on Odor Removal with High Pressure Aeration." *Water Works Eng.*, **97**, No. 23, 1350–1352 (Nov. 15, 1944).

# THE OPERATOR'S CORNER

## WHAT EVERY CITIZEN SHOULD SEE

"Clean Waters," the new anti-stream pollution moving picture assembled by the General Electric Co., has enjoyed an eminently favorable reception in its showings at recent sewage works meetings. It is hoped that the potentialities of this film as a public relations instrument are fully appreciated and that all sewage works administrators will act to bring it to the attention of the persons at whom it is aimed—Mr. and Mrs. Average Citizen of Everytown, U. S. A.

Embellished with sound and color photography, this fine picture is suitable for presentation at any public gathering. It is entirely free of commercial aspects or advertising "plugs" that might prove embarrassing to any sponsor. No attempt is made to build the theme of the picture about any fictional plot; it is mainly a factual and vivid portrayal of the growth of the pollution problem and the consequences of its existence, with a clever visual explanation of modern sewage treatment processes in the form of animated diagrams. The scenic views throughout the film are notable in themselves and will leave an impression on any audience.

"Clean Waters" is not a technical picture in any sense. It will find its best application in showings before local service clubs, women's clubs, sportsmen's groups, municipal leagues, parent-teacher meetings, high school and college classes, chambers of commerce and similar bodies. The picture will show and prove the need for adequate sewage treatment facilities in municipalities not now served by them and will engender public interest and pride in cities and towns which have already solved their sewage disposal problems. The picture can be shown advantageously several times in even the smallest communities.

Copies of the film are being made available through most of the local power utility offices and, in some cases, through the sanitary engineering divisions of the various state health departments. If these sources fail, a request addressed to Federation headquarters will be forwarded to the proper company officials.

No sewage works superintendent should fail to take advantage of this opportunity to present his profession to the public in a manner which will reflect great credit to the service he renders. Take the lead in seeing that "Clean Waters" receives a complete presentation in your town!

W. H. W.

## INGENUITY—TOOL OF THE OPERATOR *

By R. W. Simpson

*Sanitary Engineer; Gilbert Associates, Inc.; Reading, Pa.*

The Federation of Sewage Works Associations and its component regional organizations are encouraging the exercise of ingenuity by sewage works operators. Gadget contest participation attest to the interest shown by the operators themselves. The win-

* Presented at the Spring Meeting of the New York State Sewage Works Assn.; Utica, N. Y.; May 24–25, 1946.

ning of such a contest is, of course, a pleasant experience but the personal satisfaction derived from overcoming a difficult plant problem is even more gratifying.

Every sewage treatment plant has many gadgets, or refinements in equipment, which make possible better plant operation. Without the ingenuity of the operators, efficient operation of many sewage plants would be impossible. The literature contains many articles describing how this problem or that one was solved by a clever operating kink or device that was invented to fulfill a special purpose.

Remember, plants do not always run as planned on paper when placed in operation. With the many variations in flow, sewage strength and other characteristics, flexibility of plant operation is necessary. In some instances, equipment that would give excellent results under design conditions must be altered to meet unexpected operating conditions. It usually falls upon the operator to make these alterations—under the extra handicap of a limited operating budget.

It is the purpose of this paper to discuss the changes made at certain Army sewage treatment plants, as examples of what can be done to improve operation. Although some of these innovations are specific for the particular plant, many can be used to advantage in other plants.

## Removing Sand at Lift Stations

One problem faced by operators, where lift stations are installed in the sewage collection system, is the accumulation of large quantities of sand in wet wells. The quantities of grit at the Keesler Field plant became so great that at times the suction lines to the pumps were completely clogged. This condition required the expenditure of a great deal of time and manual labor in removing the sand. The work had to be done at night, while flows were low.

In order to overcome this problem, a 2-in. water line reduced to 1-in. was installed in the wet well; the reduced pipe size produced a nozzle effect with the jet of water stirring up the sand. The accumulated sand is flushed out weekly, settling out for removal at the grit chamber.

To avoid a cross connection, the flushing line is connected to the water supply by means of a double union. The nipple between unions is removed when not in use, with the physical connection being made only during actual flushing. The work can now be performed by the operator on his regular trip to the lift station, resulting in considerable saving of manpower. No manual cleaning has been necessary since the installation was made.

Other means of removing sand from wet wells can be used, in addition to flushing and manual removal. At another post, where the lift station was located in an area some distance from a populated district, the sand is hosed into a sump box and removed by a water jet pump. This method is less desirable than flushing because of the organic matter that is usually mixed with the grit as removed.

## Flushing Grit Lines

At this plant, sand and grit are removed in a double-channeled grit chamber, manually cleaned. The grit chamber is unique in that it is built about 24 ft. above the ground, at the discharge end of the pressure line from the main lift station, the elevation allowing gravity flow throughout the remainder of the plant.

Grit is washed down to a drying bed adjacent to the channel through a 6-in. cast iron pipe. Sand settling in the 90-deg. ell at the base of the grit chamber tends to plug the line.

The 90-deg. ell was removed and a tee installed, with a flushing connection caulked in the blank end of the tee. By connecting to a pressure line and flushing each time the chamber is

cleaned, this problem has been overcome. Time and labor necessary for rodding the line have been saved.

### Proportioning Gates

Operating results indicated that at the plant in question a combination of a single and two stage operation was advisable (1). In order to effect this, it was necessary to be able to control the flow of raw sewage and recirculated filter effluent to the primary tanks. The original design provided transite gates, which were held in place by slots in the concrete, allowing for open or closed adjustments only.

FIGURE 1.—Channel gate frame and gates for proportioning diverted flows.

A metal frame was devised to fit in the slots and hold steel gates of different widths. By using the proper size gate, proportioning of the flow to the primary clarifiers was made possible. Figure 1 shows the frame and two different size gates used.

### Grease and Scum Collectors

The sewage at Army installations has a high grease content, in spite of precautions to exclude and salvage it at the mess halls. Figure 2 shows the type of grease commonly found on clarifier surfaces. At several installations, water sprays were used to aid in concentration and removal of grease from the primary tanks. Figure 3 shows how such an installation can be made. A 3/4-in. pipe with 1 32-in. holes on 12-in. centers was fastened to the catwalk. The water spray created a wave action at the surface of the clarifier, causing the grease to be washed toward the grease baffle, concentrating it for removal by the scum arm.

At another installation employing circular clarifiers, the spray was installed in a slightly different manner, reportedly giving excellent results. A 45-deg. ell was installed in the end of the water line at the center of the tank and a second spray installed running from the center of the tank to the circumference. The effect of this second spray line was to keep the scum washed up toward the scum trough at all times.

The installation of scum concentration sprays is not applicable only to circular tanks. A water line, drilled as before, can be installed near the effluent end of rectangular tanks. Scum will then be washed toward the scum trough. Usually, however, the return flights on the sludge collecting mechanism are sufficiently efficient to eliminate the necessity for a water spray on rectangular clarifiers.

FIGURE 2.—Typical scum accumulation at primary tank of an Army sewage treatment plant.

Occasionally the scum accumulation at the primary clarifiers could not be removed by the scum arm. Manual skimming into the scum troughs was necessary. One of the primary clarifiers was so constructed that the scum trough was under the catwalk, making this work hazardous to the operator. A trap door, hinged at the side, was cut into the catwalk, making access to the scum trough easier. This change not only facilitated the skimming operation, but also removed a plant safety hazard.

## Water Level Indicator

The primary clarifiers, as well as the grit chambers, are well above the ground. It is not possible to observe the surface of the primary clarifiers without ascending a flight of steps to the catwalk. Since the flow to the sewage plant is dependent upon the operation of pumps at a lift station some distance away, the volume of sewage being handled changes rapidly. Each time a pump starts to operate, the flow increases, while recirculation of filter effluent to the primaries is at

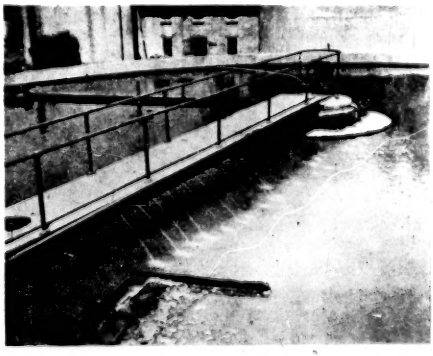

FIGURE 3.—Water spray used for concentration of primary tank scum.

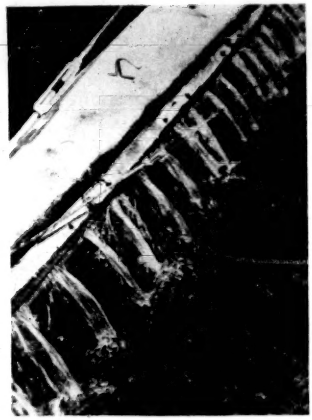

FIGURE 4.—Faulty distribution by revolving distributor.

a constant rate. When the raw sewage flow increases rapidly, there are times when the primary tanks become flooded, filling the scum well through the scum troughs.

To notify the operator when the level in the primary clarifier is dangerously high, a float was installed in the overflow channel. This gauge consists of a gallon jug as a float, a short piece of 8-in. transite pipe as stilling well, a short length of tape, a pully and strip of metal on a wooden gauge—all material being available from salvage. The gauge indicates the level of sewage in the overflow troughs. Although this gauge is used for visual warning, a buzzer or switch could have been installed to give an audible warning or to stop recirculation pumps.

## Relief Valve

In the design of the treatment plant, the hydraulics of the line carrying the primary effluent to the filter were faulty. The line became air bound, causing the filter distributor arms to whip and run at uneven speed. Since a larger line was required, the solution of this problem was rather difficult, without making major replacements.

A piece of 6-in. transite pipe was inserted into the vertical line from the primary clarifiers as an air vent on relief valve. The submergence of the pipe was varied by trial and error until it was finally located in such a position that the air binding of the line ceased. In this case, a simple device solved the problem and eliminated the necessity for costly alterations.

## Revolving Distributors

Uniform distribution of sewage over the trickling filter medium is very important in order to maintain a good active filter growth. The distributors, as originally installed at this plant, have rectangular orifices in the sides of the arms with narrow strips of metal fastened to the edge of the arm as the means for distribution. As a result of the uneven distribution, shown in Figure 4, rings of unequal filter growth developed. By experimentation, a splash plate made of light-weight galvanized iron was developed (Figure 5) to replace the narrow original strips

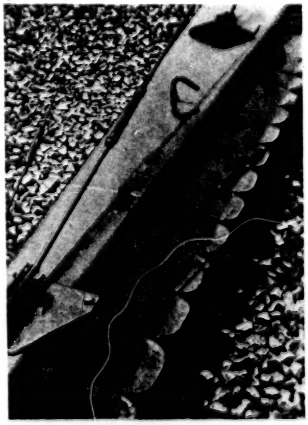

FIGURE 5.—Scalloped splash plate designed to improve distribution on filter.

FIGURE 6.—Improved distribution by scalloped splash plate.

above and below the orifices. The distribution obtained with this improved splash plate, shown in operation in Figure 6, resulted in much more uniform filter growth and increased plant efficiency.

Observation of the filter media indicated that the stone around the center pier was receiving very little liquid from the first orifice in the distributor arm. Not only was some of the filter being wasted, but this damp area provided an excellent place for filter fly development.

A hole was drilled into the arm and a 1-in. sleeve welded in place. A short length of pipe, bent in the middle and flattened at the end, was installed in the sleeve, providing better distribution over this previously neglected area, as shown in Figure 7.

Improvements of this nature cannot be made overnight; it takes patience and persistence on the operator's part. In this instance, at least six different pipes were used until one was finally bent and flattened to give the desired results.

## Sludge Sampling

What operator has not had to clean a sludge pump? It is, at best, a messy job. The designer of this particular plant never cleaned a sludge pump—that is evident. There was no waste line from the building nor a water service for cleaning up. A waste line was layed, by the operators, to drain the pump house. A water line was then installed to facilitate clean-up functions.

Sampling of raw sludge was also overlooked in design. A plugged drain on the discharge line of the pump was threaded so that a sampling line with quick-opening valve could be installed. Sampling was then possible, as well as convenient drainage of the pump for cleaning purposes.

Since it was apparently not deemed necessary to sample raw sludge, neither was it thought essential to sample digested sludge or supernatant liquor. Supernatant withdrawal lines at several levels were provided, but no sampling connections. Since these lines were of 6-in. cast iron, it was possible to tap and thread them. Two-inch sampling lines, with quick-opening valves, were installed and carried to a deep sink, for convenient sampling of sludge or supernatant liquor.

## Sludge Recirculation

The problem of digester scum can be overcome by keeping the scum soft and broken up. Returning sludge or water over the top of the scum is

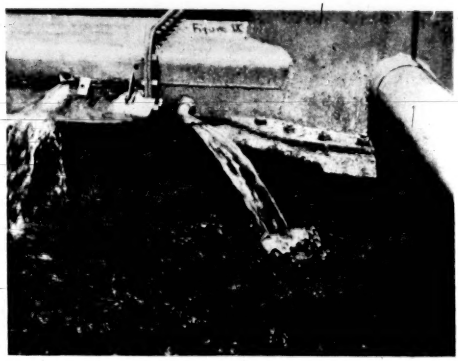

FIGURE 7.—Supplementary orifice for dosing stone at base of revolving distributor.

very beneficial for this type of control. This method of scum control was practiced some years ago at the Buffalo, N. Y., sewage treatment plant, with very good results.

At Keesler Field, a standpipe was installed, valved at the top, so that liquid could be pumped in at the top of any of the digesters for the purpose of scum control. Recirculation of sludge was required only a few times, as rapid digestion and dissipation of scum took place soon after the practice was started.

## Utilization of Liquid Sludge for Fertilizer

Keesler Field, located on the Gulf Coast, is in a very sandy area. When the top soil was stripped away in preparing the airfield, growth of grass was very sparse. After two years of fruitless effort, using commercial fertilizers, sludge came to the rescue.

Dried sludge provided the humus necessary to hold moisture in the soil, as well as valuable mineral elements. Bermuda grass, which grows well in this section, thrived in each area treated. In an attempt to speed up the process of sludge treatment of the airfield, the use of wet sludge was inaugurated with very satisfactory results. Trucks equipped with 1,000-gal. tanks, previously used for watering shell roads, were available. One of the trucks is shown being loaded in Figure 8. The fine orifice sprinklers installed beneath the rear of the tank were replaced with a header pipe and four 2-in. nipples with 45-deg. fittings attached for wide distribution.

The problem of filling the trucks now became apparent. A tee was removed from the supernatant line at one of the digesters and replaced with a cross. A valve and 90-deg. ell were attached, as shown in Figures 8 and 9. The trucks were then able to drive beneath this connection and fill up with wet sludge, drawn from any level of any one of the digesters.

These trucks distributed the wet sludge over barren sandy areas. After drying, which took place rapidly, the sludge was disked into the soil. A good stand of Bermuda grass was evident shortly after a single treatment.

## Sludge Bed Partitions

In the design and construction of the Keesler Field plant, creosote treated planking was used to separate the sludge drying beds. Under the hot Mississippi sun, these partitions soon warped leaving large gaps be-

tween the planking. It was impossible to fill a drying bed without having sludge run through to the beds on either side. Stripping of these cracks was resorted to in an effort to overcome this difficulty. Two-inch strips of wood, ½-in. thick, were nailed over the cracks for this purpose. The solution worked out very well.

## Sewage Samplers

It is readily admitted that sewage sampling is a problem. The results of sewage analysis are no better than the samples taken. Nearly every sewage treatment plant has a special sampler which takes the guesswork out of sampling.

Figure 10 shows two samplers developed to give representative samples. The sewage sampler (right) is a galvanized iron can with a capacity of 1 pint. A spout with a 1-in. opening is provided to allow sewage to enter the sampler and for ease of pouring when emptying. A small hole, ¼ in. in diameter, is punched in the top as an air vent. Since the air vent is small, the sampler cannot fill rapidly, but the entrance hole is large enough to allow solids to enter. This sampling device can be attached to any length pole, providing access to deep manholes, channels, wet wells, etc.

The sludge sampling device shown in Figure 10 (left) is quite cumbersome to handle, but the samples obtained are very accurate. A long pole with a hinge in the center makes the sampler somewhat unwieldy. A can made of a discarded shell case is held in place at the bottom by a spring clip. A metal cap covers the can and is held in place by a spring under compression. By pulling on a cable attached to the cover, the sampler is opened or closed at the desired depth. When the sampler is withdrawn from the sludge, the can is removed and the sample transferred to another container.

## Other Gadgets

Many other gadgets were developed at Keesler Field to increase plant efficiency. To remove the guess work in digester heating, the hot water lines leading to the heating coils were tapped and well-type thermometers installed. Boiler operation could then be controlled. An Aqua-stat installed in the boiler and connected to the circulation pump controlled circulation of hot water at a predetermined temperature.

To overcome a safety hazard from fumes in the lift station dry wells, vent fans were provided. The fans were installed in the building wall,

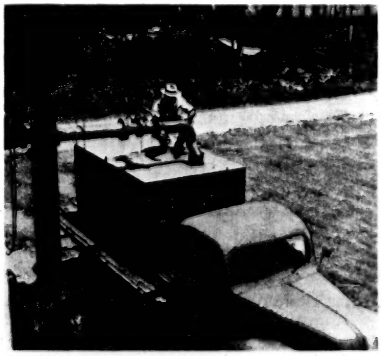

FIGURE 8.—Tank truck being loaded with liquid sludge to be applied as fertilizer.

FIGURE 9.—Arrangement for drawing liquid sludge to tank trucks.

connected to a 90-deg. tin ell and an 8-in. transite pipe. The pipe ran through the floor to the bottom of the dry well, allowing the fan to draw out the heavy noxious fumes accumulating there.

## Summary

1. Many plants are bothered with sand accumulations in wet wells. Flushing lines can be installed to stir up the sand for pumping to the grit chamber.

2. Lines carrying grit plug up very easily, especially at bends. Flushing connections may be provided and should be used regularly where this may occur.

3. Where diversion of flow from open channels is desired, ordinary shear gates can be replaced with frames designed to accommodate gates of different widths, thus increasing or reducing the capacity of the channel.

4. If large amounts of scum are encountered at primary clarifiers, water sprays can be installed advantageously to assist with the collection and concentration of the scum.

5. In open channels or wet wells, level indicating gauges can be made to assist the operators. Visual or automatic gauges can be devised from scrap material around the plant.

6. Surging or air binding in lines can be overcome by simply inserting an air line below the surface, adjusting the submergence until the binding stops.

7. Distributor arms which do not give uniform distribution over the filter medium may reduce plant efficiency. Better distribution may be obtained by installation of scallop type splash plates on the arms.

8. Sludge sampling is necessary for plant operation. Sampling lines can be installed at cleanout plugs on sludge pumps. Cast iron lines can be drilled and threaded for installation of sampling lines.

9. Scum accumulations in digesters can be controlled by keeping the scum wet and broken up. Recirculation of sludge or supernatant over the scum can sometimes be provided to do this.

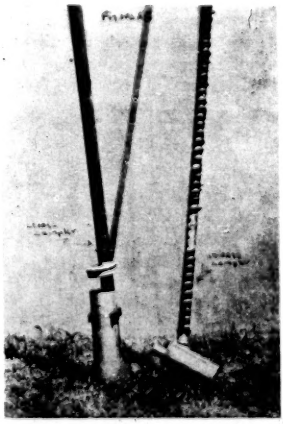

FIGURE 10.—Sludge and sewage samplers, left and right, respectively.

10. The use of wet sludge is sometimes advantageous for stimulating the growth of grass on sandy soils. Watering trucks can be used for this purpose.

The plant gadgets discussed here are only a few of the many that have been developed by operators during the war. The ingenuity of plant operators in overcoming operating difficulties and improving plant efficiency should be fostered and encouraged by the engineer in charge. Without constructive thought and action among the men who actually do the work, the designing engineer and equipment manufacturer would be handicapped in developing newer and better methods of sewage treatment.

### Acknowledgment

The author wishes to acknowledge the assistance of L. C. Ward, Chief Operator, and other operators of the Keesler Field sewage treatment plant in the development of many improvements that made possible the high efficiency maintained.

### Reference

1. Simpson, R. W., "Bio-Filter Operation at Keesler Field, Miss." *Water and Sewage Works*, 93, 9, 367 (September, 1946).

# SMALL PLANT OPERATION *

By Herbert O. Johnson

*Superintendent, Belgrave Sewer District, Great Neck, N. Y.*

For the purposes of this paper a "small plant" will be defined as a municipally owned and operated sewage treatment plant with a designed capacity of up to 1.0 m.g.d. The plants encountered within this range will, of course, include all types known to the science today—from the neglected septic tank to the well-operated secondary treatment plant. "Small plant operation" is a general term for title purposes only and this paper will be confined to generalities and certain pertinent details peculiar to small plants and their operation.

## Sound Engineering a Prerequisite

The first steps toward good operation originate with the Engineer. Good judgment and design on his part can greatly simplify and reduce labor involved in routine operation. He should provide the operator with such items as (*a*) an ample number of water hose connections, strategically placed, (*b*) convenient sampling points for sewage, (*c*) amply sized sampling lines for sludge, (*d*) extra push buttons for remote control of equipment, (*e*) light manhole covers wherever possible, (*f*) railings around open tanks, (*g*) adequate lighting around structures, etc. He should also include in his specifications a list of tools, wrenches, grease guns and other equipment needed to maintain and service properly all plant equipment and structures.

All this is, of course, fundamental engineering and should not require elaboration. It is amazing to note on plant inspections, however, the number of exceptions to good engineering practice, to wit: grit chambers located in deep basements without adequate means for raising grit to grade (in this connection, the writer does not consider the apartment house type of ash hoist as adequate to handle grit); comminutors located under stairways; sewage meters with pressure piping, flushing lines and valves located in wet wells; guided stem vertical check valves in sewage pump discharge lines; man-

* Presented at the Spring Meeting of the New York State Sewage Works Assn., held at Utica, N. Y., on May 24–25, 1946.

hole-step ladders and ship-type stairways; valves located in almost inaccessible places, etc., etc. Another item frequently mentioned by operators is the by-pass line that should have been built. The writer has never heard an operator complain of too many valves, but many times he has heard the lack of a certain valve decried. The foregoing is not intended to be critical but is illustrative of what can and does happen.

Small plants are very often designed to appear as something other than a sewage treatment plant. Buildings are designed to conform to neighborhood architecture and more or less extensive landscaping is provided to carry out the overall effect or to camouflage tanks and functional structures. This is all very well and serves an admirable purpose but always means more work for the operator on maintenance and upkeep. Such work should be done by extra labor provided for that purpose or care and maintenance of grounds should be turned over to the park department.

## Specifications for the Operator

The small plant operator must of necessity be a versatile and composite type of individual. He should be an electrician, pipefitter, machinist, gardener and book-keeper with a leaning toward practical sanitary engineering and chemistry. He should have a generous amount of ingenuity, adaptability and diplomacy in his make-up and a large amount of conscientiousness. In addition to this he must have a tough stomach and a willingness to perform hard labor incident to tank and grit chamber cleaning, clearing of pipe line stoppages and sludge cake removal.

The smaller plants will usually have only one operator who may even be on a part-time basis. The larger plants will usually have a chief operator and an assistant operator or laborer, and in one plant to the writer's knowledge four men are required to handle a flow of 0.5 m.g.d.

The selection of operators is unfortunately often made on the basis of politics and personal friendship, with little thought given to the actual physical and mental requirements of the job. The activities of the state health department through the Public Health Council in setting up qualifications for sewage works operators, and the Civil Service laws as enacted recently, have tended to lessen political activity and influence in the selection of operators.

The writer has knowledge of one case where a penuriously inclined municipality hired a friend of the Mayor to take charge of their recently completed high degree treatment plant of small capacity. The stipend was low — very low indeed — but the operator was to be allowed to carry on his own personal business as a sideline. As might be expected, the sewage treatment plant actually became the sideline and in a short time the plant was inoperative — that is, except for the by-pass line. Conditions soon became intolerable and, following a normal course of events dictated by circumstances, and not without headaches galore to those involved, the now educated Village Fathers have a competent operator who is doing a good job and turning out an excellent effluent. His efforts were just recently rewarded with a raise in pay.

The small plant operator usually works under very informal conditions. He is usually a friend of the city officials and well-known in town. He is his own boss as long as things go well and if they do not he should know the right answers. He does not have to punch a time clock and can usually arrange his work to suit his affairs.

On the other hand, his vacation is usually a catch-as-catch-can affair and his wife will probably often remark that he loves the plant more than he loves her. This statement is due, of course, to the time spent at the plant

after hours in clearing stoppages from non-clog pumps, etc.

In addition, he may be called upon occasionally to perform certain extra-curricular duties such as painting the Mayor's kitchen or installing a drain in Commissioner Brown's back yard. These jobs may be cheerfully done but always result in less time for the plant. As routine plant operation work increases, this kind of activity will surely become onerous and consequently detrimental to the operator's state of mind and to plant operation in general.

## Common Small Plant Experience

The average small plant usually starts off under excellent auspices. The initial flow may be as low as 5 to 10 per cent of the design flow and operating results are perfect. The effluent is uniformly good and sludge digestion proceeds without a hitch. Sludge withdrawals are far between and cake is allowed to remain on the beds until very dry and light. At the same time there is ample time to spend in the laboratory to prove the good results obtained.

As the ratio of actual flow to design flow increases, however, plant operation changes. The quality of the effluent deteriorates, and the labor involved in routine operation such as channel cleaning and sludge pumping increases. Also, unexpected and sometimes unheard of kinks develop in mechanical equipment. The digester may become obstreperous and foam all over the yard. Sludge cake must be removed earlier to make room for more sludge from the digester.

At this time the operator is a very busy man and does not have much time for laboratory work. He will also try to interest some local farmer or nurseryman in the sludge cake, the object being to have the farmer clear the beds. This arrangement is a good one, but is apt to bog down on the fact that the farmer often cannot take the sludge when ready due to other work. So the operator will bend his weary back again or try to get the Council to authorize extra labor.

## Laboratory Functions

Laboratory work in a small plant should be cut down to a bare minimum. In the smallest plants, settleable solids, residual chlorine and pH determinations will suffice. In larger plants, suspended solids and sludge solids and volatiles should also be run. B.O.D. work on a routine basis should be carried on only at secondary treatment plants.

In contrast to the large plants, with regular technical personnel and continuous compositing of samples, the small plant operator will be lucky to get in one or perhaps two 6-hour composite samples a week, and this composite will represent only the day flow. Sludge samples will usually be taken at weekly intervals or less. Laboratory work can be carried on in two ways — either sandwiching it in between other routine work, or setting aside one day for laboratory work and reducing routine work to a minimum. The second alternative is the better one.

## Records

Modern plant operation requires that control data and operating records be kept. These will serve to provide a comprehensive overall picture of plant operation and will also serve a purpose in future studies of sanitation problems as they arise. The operator's charts should be as complete as possible but should contain no extraneous matter or unnecessary data. Records should be honestly kept and not "fudged in." The standard forms of the New York State Department of Health are excellent ones to use and can be adapted to any type of plant.

## The Annual Budget

There is one other problem that should be brought out, if only briefly. This problem is one that concerns the

large plant operator as vitally as his smaller brother. Reference is made to the annual estimate of expenses for the fiscal year following, commonly known as the Budget.

The operator usually does not have too much to say about this matter; although he may be asked what he thinks he will need and to draw up a list. This list, if honestly drawn up to cover all items and to provide for unexpected contingencies, and a couple of dollars to attend mettings such as this one, will inevitably be high and will just as inevitably be cut to shreds. So the operator prepares an estimate barely covering the minimum essential requirements of labor and supplies and still probably finds it slashed arbitrarily. Under such a system, needed improvements are long delayed even to the point of breakdown of equipment and failure of processes.

In conclusion, the writer repeats that he has highlighted only a few of the problems of the small plant operator and his plant. In order to get a full picture, with all its ramifications, it is almost necessary for one to serve as such an operator for a time.

# FACTS ABOUT CHLORINE *

By Wilmer H. Koch

*Works Chemist, Niagara Operations, The Mathieson Alkali Works, Niagara Falls, N. Y.*

Chlorine is an element which belongs to the same family as iodine, bromine and fluorine. Iodine is a solid at room temperature, bromine a liquid and fluorine and chlorine are gases.

## Chlorine Manufacture

Chlorine is made by the electrolysis of common rock salt. An electric current is passed through a saturated solution of the salt, caustic soda and hydrogen gas being liberated at the cathode while chlorine is set free at the anode. The chlorine gas is passed through concentrated sulfuric acid in a tower which removes all the moisture. This is necessary because wet chlorine is very corrosive and would rapidly attack the container in which it is shipped. Pure dry chlorine is relatively inert.

The chlorine is then cooled and compressed, which causes it to liquefy. From the storage tanks it is transferred to the various containers in which it is shipped, ranging in size from 100-lb. cylinders to tank cars which hold as much as 30 tons.

## Preparation of Containers

Before filling, each cylinder is carefully steamed out, cleaned and dried to remove all rust and dirt. A light is lowered into the cylinder for visual inspection of its condition. The valve, which has been previously removed, is completely reconditioned; the packing is renewed, a fusible plug is put in place and the valve is tested for leaks. The cylinders are filled overweight and blown down to the proper weight, which operation removes most of the air and non-condensible gas from the gas space in the cylinder. After filling, the cylinders are painted with aluminum paint which has been found to have a lower heat absorption than other types of paint previously used.

## Chlorine Storage and Use

In the cylinders the chlorine exists as a liquid. The cylinder is left with about 15 per cent free gas space above the liquid to provide for expansion on any ordinary increase in temperature. As the cylinder is received at an ordi-

* Presented at Spring Meeting of New York State Sewage Works Assn.; Utica, N. Y.; May 24–25, 1946.

nary temperature of 72° F. the pressure will be approximately 85 lb. gage. If the cylinder is stored outdoors in the winter and its temperature falls to 32° F., the pressure will fall to about 39 lb. At 100° F. the pressure will be about 140 lb.

Containers, if stored in the cold, should always be brought inside into a heated room for some time before use so that there will be sufficient pressure developed to afford a ready flow of the gas. A chlorine container acts much like a boiler. If the temperature outside the container is raised without the release of gas the pressure will rise. The difference lies only in the fact that the boiling point of chlorine is −30° F. That is why it already has a cylinder pressure as high as 85 lb. at 70° F.

When a cylinder valve is opened the chlorine gradually evaporates from the surface of the liquid and at the same time the temperature of the liquid falls. The heat loss must be supplied by the atmosphere surrounding the container to maintain the pressure. If the chlorine is removed faster than this heat can be supplied, the liquid cools rapidly and eventually a frost line shows on the surface of the container and the pressure is considerably lowered.

If a sufficiently large quantity of chlorine is required in an operation to cause containers to frost, the containers should not be heated externally. Instead, it is better to hook up several containers to a manifold, drawing from all of them at the same time.

Placing containers in hot water or surrounding them with steam is very bad practice and is likely to cause serious trouble. At the boiling point of water the pressure in the cylinder will rise to 540 lb. Cylinders and tanks are tested hydrostatically to only 500 lb. so, if heated to excess, they might burst with attending consequences.

Precautions are taken to prevent this particular occurrence from taking place. Each cylinder is supplied with a plug containing a fusible alloy. If the cylinder is overheated this plug will blow similarly to a safety valve on a boiler and allow the chlorine to escape rapidly. The fusible alloy softens at between 157°–165° F.

From each type of container, chlorine may be removed as either gas or liquid, depending upon the position of the container. If the chlorine is removed as a liquid in the operation, there is no particular decrease in the pressure since the heat loss due to evaporation of the chlorine takes place outside of the container and in the solution to which the chlorine is being added.

Chlorine also forms a hydrate by addition to water. At a water temperature of about 40° F. crystals of chlorine hydrate will separate when chlorine is applied. Oftentimes the crystals form in chlorinators in the winter where the room is unheated and where the water is cold. If this reaction is allowed to continue the crystals will plug up the orifice of the chlorinator. Raising the temperature of the water will cause them to dissolve and will remove any obstruction. The formation of hydrate crystals may be prevented by inserting a small heater in the water supply line, raising the water temperature to between 50 and 55° F. In some instances infra-red lamps have been used successfully.

Moisture should never be allowed to get back into the chlorine lines. Wet chlorine is very corrosive and attacks iron and copper to form the chlorides. These chlorides can cause no end of difficulties in plugging up orifices and chlorine lines.

Chlorine containers should always be handled with care. They should not be stored next to heated radiators. Cylinders should not be placed in an upright position, without bracing, where they may be knocked over. The protective caps over the valve should be kept in place unless the cylinder is in use.

Valve stems which are frozen shut should not be forcibly opened with sufficient pressure to twist the stem. If a chlorine valve is leaking at the stem, it should be tightly closed and the packing nut and packing gland removed, the packing replaced and the packing nut and gland returned to place. If the valve is leaking at the outlet the stem should be closed tightly and the cap screwed tightly over the outlet, after being sure that the asbestos gasket is in place in the cap. The cap will hold enough pressure to enable the cylinder to be removed to a safe place.

In the event neither of these provisions apply, the chlorine should be run into a milk of lime solution and absorbed or the cylinder should be placed out into the open, if the surroundings are relatively uninhabited, and allowed to leak until empty. All these operations should be carried out while wearing a protective mask.

## Action of Chlorine

Chlorine is the cheapest and one of the most effective agents for oxidation. It finds its use in sewage treatment because of its ability to kill harmful bacteria. It does this either by suffocating bacteria of the type which cannot live without oxygen, by direct chlorination or by the formation of oxygen in the nascent state which in effect "burns" the organic matter of which they are composed. It also forms, with water, hydrochloric and hypochlorous acids, which are both very deleterious to organic life in many forms.

In the same manner other objectionable organic compounds are rendered less so by its action. The exact mechanism of these reactions is not completely known and is subject to considerable difference of opinion. Generally speaking, water or sewage which has had sufficient contact time with chlorine and which carries a residual chlorine content at the end of that time is considered to be pathologically inert.

The amount of chlorine contained in a sample of sewage or water is generally determined by measuring the intensity of color produced on the addition of o-tolidine reagent. Other tests such as the well-known starch-iodide test or the alpha napthaflavone test may be used and should be when there is any question of the results obtained by the o-tolidine test. Sometimes these interferences may be compensated for but many times results are obtained which are very much open to question. If the difficulties cannot be resolved by means available at the spot the operator should always procure the services of his state board of health engineers.

It is advisable that all operators become familiar with the latest modification of the o-tolidine test known as the OTA test. This method is discussed and outlined in an article by Gilcreas and Hallinan in the December, 1944 issue of the *Journal* of the A.W.W.A.

## Chlorine Hazards

Chlorine is a noxious gas. It was the first gas used by the Germans in World War I. It belongs to the class known as lung irritants.

The best means of avoiding its effects is to get away from it as quickly as possible. If the concentrations are sufficiently high to cause distinct irritation of the membranes of the nose and throat, a protective mask should be worn when working with it. There is advantage in that chlorine is readily detected by smell and is thus relatively easy to avoid because its presence is easily noted. Unless trapped where it is impossible to get out, it is not easy to be seriously exposed because it is difficult, if not impossible, to remain for any but the shortest time in concentrations which are serious.

### *Physiological Effects*

Chlorine is readily soluble in water and for this reason attacks easily the

membranes of the nose and throat, bronchial tubes and lungs. An immediate irritation is set up which causes coughing and, in the case of large amounts, a choking effect. Only rarely will death occur on sudden exposure and then only because of the reflex action caused by heavy concentrations. The chlorine dissolves in the water of the membranous tissues where it hydrolizes to form hydrochloric acid. This acid breaks down the cell tissue walls, releasing the fluid in them.

If the concentration is high enough or the exposure long enough, this action in the lungs causes an edema or watering of the lungs. The water proceeds to fill up the air sacs of which the lungs consist. The watery fluid interferes with the transfer of oxygen to the blood and causes anoxemia. The blood thickens from lack of oxygen and the whole process proceeds through cyanosis (blue stage of asphyxia) to final cardiac collapse. The victim actually dies either from shock or drowns in his own body juices. Short of death, the effect is to produce pulmonary pneumonia and all the treatment is the same as for this well-known affliction.

*First Aid*

In the treatment of chlorine exposure cases there are several things to be carefully remembered. Because of the fact that in many cases there is a delayed action, the victim should be given complete and absolute rest whether he thinks he needs it or not. If necessary, this should be enforced and the patient compelled to lie down. The rest period should extend from 24 to 48 hours and nothing should be done to increase in any way the heart action.

For mild cases which produce nothing more than an irritation of the nose and throat with attendant coughing, breathing small amounts of chloroform has been helpful.* Others have had relief from drinking milk. Many things have been suggested for relief in this condition but most of them are, it is believed, psychological in their effect.

For more severe cases absolute rest is essential, preferably in a prone position. The feet should be slightly raised to assist in the drainage of the lungs; oxygen should be administered where there is difficulty in breathing and the patient should be kept warm. Warm drinks may be administered, such as warm tea or coffee. Alcohol is contraindicated as is also morphine. Restlessness and apprehension may be combatted with guarded doses of barbiturates only under the direction of a physician, but the relief obtained by the administration of oxygen is the best means of quieting and reassuring the patient.

Where anoxemia has developed the treatment is the same as for regular cases of pneumonia. It is not desirable to mix either helium or carbon dioxide with the oxygen since the difficulty is not bronchial obstruction or lack of carbon dioxide in the blood. Oxygen administration should be continued at frequent intervals until there is no further indication of cyanosis. In cyanotic conditions venesection is called for to remove some of the load from the heart.

Absolute rest must be continued for some time after respiratory symptoms disappear and resumption of exercise should be gradual to avoid fatigue and exhaustion.

The milder cases always recover. Most deaths occur within 24 hours and these are due largely to broncho-pneumonia which is more apt to occur in men with pre-existing pulmonary diseases. Psychosomatic complaints may continue for years.

*Precautions*

Actually, chlorine is one of the least offensive of the so-called poison gases. Its effects are easily avoided. First, get away from it if you have no busi-

* This is not a recommended procedure for inexperienced personnel.

ness there, and if your business takes you there, wear a protective mask when working with it. It is always well to remember that a protective mask is not a cure-all.

If the concentration of chlorine is very high, even though the mask removes all of the chlorine the amount of oxygen remaining is not sufficient to sustain life and an oxygen mask will be required. There should be, however, some type of protective mask wherever chlorine is used. These masks, with their canisters, should be inspected periodically so that they will be in usable condition when they are most required. Once the cap which seals the canister has been removed and the canister has been used it should be replaced by a fresh canister.

Lacking a mask, get out and stay out. The chlorine will be gone before long with the windows and doors open. It is best to handle chlorine with respect rather than contempt for its hazards.

## BARK FROM THE DAILY LOG*

By W. W. Mathews

*Superintendent, Gary (Ind.) Sanitary District*

**August 23, 1940**—O-Day is upon us! For the past two weeks we have been training operators; testing pumps, blowers and other equipment and otherwise preparing for this occasion. Pumping of sewage to the grit chambers and primary tanks was begun at 10:45 this morning. The die is cast!

The operation staff (including your *Logger*) is more or less on edge as each primary treatment unit of the plant is introduced to its function. Yet we are well prepared, since all of the outside men worked as inspectors during construction and are familiar with the location and purposes of piping, valves and structures.

Probably the most complicated responsibility of the outside operators is in pumping and transferring raw and digested sludge. In each of the four sludge control houses there are 38 valves for handling the flow of sludge to five primary and three secondary digesters, and to the sludge beds. This piping, affording maximum flexibility for pumpage and transfer, is quite confusing at first glance. With careful instruction as to the object of each operation and with the aid of arrows and labels on the various lines, however, the men got the "know how" quite rapidly. An outside operator in this plant must have knowledge of the location and purpose of more than 300 valves!

The pump and blower house staff, which we classify as "inside" operators, worked during construction for about a month, while the gas engines, blowers and pumps were being installed. Consequently, they are also prepared to operate and maintain the equipment for which they are responsible.

As we begin to take the flow, one gas engine driven pump is in service, with the engine jacket water being used to heat the primary digesters. The engine is operating on public utility gas. Operation went smoothly with no mishaps.

**August 24**—The first raw sludge—quite thin—pumped to the primary di-

* To diversify the content of the *Log*, arrangements have been made to have Mr. Mathews alternate with W. A. Sperry in furnishing future columns. This introductory contribution by Mr. Mathews relates experiences in the commencement of operations at the Gary activated sludge plant, which serves a population of 100,000.—*Editor.*

gesters. Several sludge pump stoppages on account of small sticks, chips and other residual construction debris puzzled the outside operators, who had taken great pains to remove such material from piping, conduits and tanks before the flow was admitted.

**September 17**—Primary treatment having been in operation for 25 days, four of the aerators were filled and placed in service today. Application of air was begun at noon without flow through the tanks.

**September 18**—Secondary treatment started in earnest as flow is admitted to the aeration tanks and return sludge pumps are started. One gas engine driven blower is being operated on utility gas fuel, giving us additional jacket water heat for the digesters.

Stoppages in the raw sludge suction header keep us from leaning over the rail at the aerators to watch the sludge "activate." Your *Logger* and his chief operator were kept on the job until midnight.

**September 20**—Everything running smoothly except that primary tank sludge. One stoppage followed another, engaging the day crew until midnight in backflushing the suction header.

**September 21**—Enough of these late hours playing nursemaid to the raw sludge pumps! Today we began pumping down the primary tanks to check the sludge hoppers and suctions and well worth the trouble it was. The yield from the No. 1 unit was a short piece of 2 by 4, a small paint bucket and an assortment of nuts, bolts and washers; the sludge hopper of the No. 2 tank contained several pieces of broken concrete; and a quantity of sand was taken from the hopper of the No. 3 unit that was sufficient to block completely the suction opening.

And thus was solved our first major operation problem!

**September 24**—Noting that the return activated sludge possessed a somewhat stale and septic odor, we concluded that the 25 per cent return rate was a bit low and decided to increase it. The final settling tank effluent now has a rather milky appearance.

**September 26**—Dedication Day, with all its fanfare, floral pieces and fancy speeches by public officials. A fine crowd in attendance, all to be conducted on an explanatory tour of the plant. Among those who registered on this date were fellow *Logger* Walter Sperry and son John; Fred Nelson, Frank Bachmann and R. S. Rankin of the Dorr Co.; Milton Spiegel and G. D. Bers of the Chicago Pump Co.; and Paul J. Kleiser, David Backmeyer and J. E. Epler.

All in all, a very large day!

**September 27**—The first signs of visible activated sludge floc in the final clarifiers. The effluent, turbid and cloudy heretofore, is beginning to clear up.

**October 2**—After almost exactly two weeks of aeration we can now boast of a well developed activated sludge floc. The plant effluent is clear and sparkling and low in B.O.D. but carrying a bit more suspended matter than is desirable.

**October 3**—Time out for a very special occasion. To Chicago for the first annual technical meeting of the Federation. Many new and old friends to see and a lot of visitors at the plant from all over the nation.

**October 8**—A notable day in that the first digester gas is turned into the system and burned at the waste burner. Primary digester No. 5 is the first "producer," yielding about 50 c.f.m.

As turned over to us by the contractor, each digester contained about 5 ft. of water that had been pumped in to test the tanks for leakage. Raw sludge was pumped to the primary di-

gesters about 2 hours per shift so that tanks were filled slowly and, when full, acid digestion had been completed with the pH stabilized at 7.0 to 7.1.

Division of the daily raw sludge charge among the five first stage units represented a moderate loading and there was no indication of foaming at any time. At times, from 100 to 200 lb. of lime was added per day per tank but its effect was probably more psychological than actual because each unit holds more than a million gallons.

**October 9**—The gas flow from No. 3 digester is now turned into the system—rate about 40 c.f.m. No. 5 is producing so rapidly now that the gas dome seal was broken.

**October 18**—We have been following with a great deal of interest, and some concern, the gradual rise in blower pressure since the aeration tanks were placed in service just a month ago. The pressure has advanced from 7.0 to 7.8 p.s.i. in this short time.

It is believed that we are now receiving the first effects of the pickling liquor that is discharged to the sewers at one of the large steel mills here. These wastes have also imparted an orange-red color to the activated sludge that is quite pleasing in appearance.

**October 26**—Another important day. With the gas holders almost full, the No. 3 engine (driving a 20 m.g.d. sewage pump) was placed into service on digester gas fuel.

**October 27**—Engine No. 4, driving a 7,000 c.f.m. blower, put into service on digester gas. In converting this unit from utility gas it was necessary to change mixers because of the difference in fuel value.

**November 5**—The No. 2 aerator, which had developed very uneven air distribution, was drained and replaced by the No. 5 unit. The air pressure dropped immediately by 0.6 p.s.i. As expected, there was a goodly iron oxide deposit on the surface of the diffuser tubes of the No. 2 unit.

**November 9**—A large group of students from the Lew Wallace High School visited the plant and seemed to be generally impressed by the differences from their preconceived ideas of a sewage treatment plant.

About the time the visitors left, the water main serving the plant burst and left the sewage pumps without seals. Luckily the flow was low so that repairs could be made and operation restored before any basement flooding occurred.

**November 11**—Celebrated Armistice Day by correcting a scum problem at the No. 1 digester, which had belched a slug of scum into the gas lines and meter. Just why this unit should give such trouble we cannot say, since the piping at all primary digesters is identical. Nevertheless, operation was soon restored with little harm done after the piping and meter were flushed and the scum accumulation at the digester gas domes was hosed down.

**November 17**—For the first time, it was necessary today to light a waste burner to get rid of surplus gas. May this continue!

**December 4**—Our good luck with the gas engines has finally run out. For the past week we have been combatting a jinx that has been working overtime.

It all began with a loose valve insert on one engine, which was readily corrected by the installation of a spare head. Two days later the same engine developed a crack in the manifold and was down again. In the meantime, another engine was shut down while some changes in blower piping were made. Upon attempting to resume service it was necessary to shut down three times in two days, until the difficulty was found to be due to a minute leak in the gas meter diaphragm.

With fingers crossed, it can be reported that the engines are now working well.

**December 6** One of the aeration house Venturi meters was found to have developed a crack along a flange, probably as a result of settlement in the piping. The repair by welding was accomplished easily.

**December 20** Something new (and undesirable) has been added! A heavy discharge of oil during the night has covered 1,200 sq. ft. of primary tank surface with a 1-in. black scum. An immediate attempt was made to skim off the oil but considerable of it had already passed on to the aerators and "rainbows" were all over the place. And what a mess at our shiny new primary tanks!

**December 23** The average gas production for the 8 days preceding the "shot" of oil was over 160,000 c.f.d. Yesterday it was 89,000 cu. ft., requiring us to use purchased power for pumping.

**December 27** Insult is added to injury as another batch of oil, smaller than the first, is received. A reconnaissance party has been dispatched to locate the source.

Recovery from the first dose of oil was far from complete, with gas production at 99,000 c.f.d. but on the rise. The plant effluent was carrying 3 p.p.m. of B.O.D. and 5 p.p.m. of suspended solids "B.O." (before oil); these values are now 23 p.p.m. and 41 p.p.m., respectively.

**December 31** A glance in retrospect as the year ends discloses that we have not had too much to complain about in our first 14 weeks of operation, although we would gladly dispense with the free oil we have been getting. Mechanical troubles at equipment have thus far been vexing but not at all serious.

Experience to date has also justified some operational variations, such as the increase in rate of activated sludge return that was decided upon soon after secondary treatment was initiated, in order to keep the sludge fresh. It was originally intended to carry about 2,000 p.p.m. of mixed liquor solids but it now appears that half this concentration should be enough. Likewise, the original rate of air application of 0.75 cu. ft. per gal. has been reduced to 0.5 cu. ft. per gal., with continuing good results.

**January 1, 1941** It would have been a happier New Year if we hadn't received another batch of oil. Gas production is down to 76,000 c.f.d. and the electric meter is ticking merrily for the power company, that is—along.

**January 6** Skimming oil from the primary tanks is getting to be a daily routine now, and a tiresome one indeed! We are caught in a vicious cycle with no gas no engines no heating water no digester heat and no gas, which is where we came in. An old road roller has been borrowed and placed in position for use as an auxiliary heater for the digesters, using live steam from the boiler.

**January 13** The digesters really came to life today, the day's gas yield being 210,200 cu. ft. The decrepit road roller boiler appears to be just what the doctor ordered!

In an effort to reduce oil consumption at the gas engines, a continuous type Fuller's earth oil filter was installed for trial on engine No. 4. Heretofore it has been necessary to change the oil every 30 days.

**January 14** Another cracked manifold on No. 4 engine, but not serious.

**January 21** A sludge suction stoppage at the No. 5 secondary clarifier made it necessary to remove the unit from service for dewatering.

The auxiliary steam boiler is still in service at the digesters and gas production is very satisfactory at 197,500 c.f.d., although there was a gradual sag to 120,000 c.f.d. on the day before yesterday. But now the holders are up against the stops, giving us 180,000

cu. ft. in storage. It was satisfying to be able to light the unit heaters and waste gas burner again.

**January 31**—The source of the unwanted oil has been located at last in an industrial plant where cutting oil is used on automatic machinery. With considerable relief we note that, in spite of the oil and resulting digester trouble, gas production in January averaged 130,500 c.f.d., which supplied 87.1 per cent of the power needed for aeration and 73.6 of the power required for pumping of sewage. That cutting oils are objectionable to activated sludge treatment is proved by comparison of the average B.O.D. removal of 86.4 per cent for January with the values of 93 and 94 per cent for December and November, respectively.

**February 1**—The temperature of the digesters is now very satisfactory and the auxiliary steam boiler has been shut down.

**February 22**—Last month the digesters were too cold. Now, believe it or not, the temperature of two of them is over 100° F. and it becomes necessary to shut off the heating coils! We also had to open the heat exchanger by-passes to reduce the heat intake of the circulating water.

**March 1**—February broke several records. First, 100 per cent of the power required for pumping and aeration was supplied by the gas engines. Second, no oil was discharged to the sewers, finally, by coincidence, suspended solids and B.O.D. removals were identical at new highs of 94.8 per cent.

And so, at O-Day plus 178, we consider that the shakedown cruise is over and that the Sanitary District of Gary now has a new utility that will serve it well through the coming years—a utility that is a credit to its designers, its builders and to the people it will serve.

## INTERESTING EXTRACTS FROM OPERATION REPORTS

CONDUCTED BY LEROY W. VAN KLEECK

### Summary of Plant Operations for the Year 1944 of the Greater Winnipeg Sanitary District, Winnipeg, Manitoba *

BY D. L. MCLEAN, *Superintendent*

The works constructed and operated by the Greater Winnipeg Sanitary District consist of an intercepting sewer system and a sewage treatment plant which collects and treats the sewage from some 260,000 inhabitants of the cities of Winnipeg and St. Boniface, the town of Transcona and the municipalities of St. Vital, East Kildonan and West Kildonan. The general arrangement of the sewage treatment plant is shown in Figure 1.

* For previous extracts see THIS JOURNAL, **14**, 5, 1096 (Sept., 1942) and **17**, 1, 139 (Jan., 1945).

*Digester Scum*

Digester scum may vary from foam-like material consisting of particles of sludge supported by gas bubbles to accumulations ten or more feet in depth having sufficient surface strength to support an adult person.

At this plant there has been special opportunity for observing the formation of digester scum. When the plant went into operation, digestion was carried out with two primary digesters equipped with Dorr Turbo-mixers and two secondary digesters without any

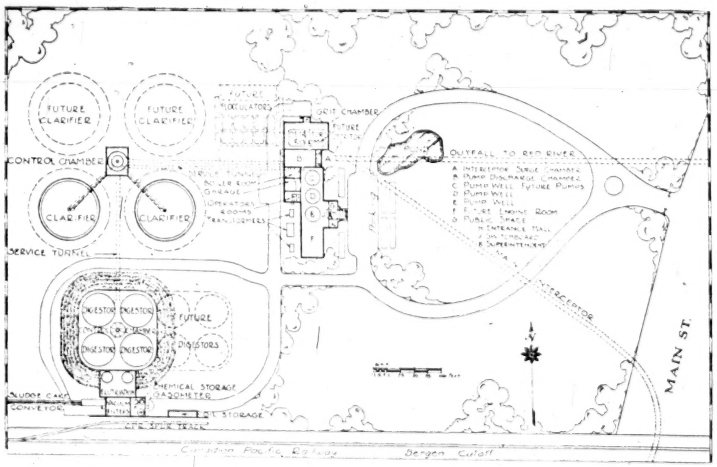


FIGURE 1.—General arrangement of sewage treatment plant of Greater Winnipeg Sanitary District. Future extensions shown with present installation of 25 m.g.d. capacity.

stirring equipment, although provision was made in these secondary digesters so that mixers could be installed when required. Following digestion, the sludge was washed and settled in two elutriation tanks.

As the war loading came on the plant, the four digesters were used as primary digesters. From this it was possible to observe from day to day the value of the Dorr Turbo-mixers. On each digester a daily record was made of the scum level so that the height of scum above the water level of each digester was recorded. The removal of this scum accumulation from the digesters gave another source of information.

The following observations were made:

1. The digester scum weighs from 50 to 53.5 lb. per cu. ft.

2. It consists of particles which are supported by gas bubbles and of which some 99.9 per cent will sink if freed from the supporting gas bubbles. Usually only a small portion of the scum particles are longer than 1/8 in.

3. The accumulation can be settled by stirring with Dorr Turbo-mixers or by sprays.

4. The material can accumulate from overloading of the digesters, lack of heat or other abnormal conditions.

5. This scum, when ground to pass a No. 30 standard mesh sieve and held on a standard No. 100 standard mesh sieve, will digest in the same way as other raw sludge.

6. The scum on the two digesters equipped with Dorr Turbo-mixers never gives trouble as long as the raw sludge solids and temperature are controlled.

7. The scum on the two digesters not yet equipped with stirrers accumulates to depths of 8 to 14 ft. so that this must be removed about once a year. Such removal is a dangerous and costly work.

8. Turbo-mixers permit 20 to 25 per cent additional raw sludge solids to be put into a digester.

9. By installing Turbo-mixers in the two digesters which now afford the di-

gestion capacity of only a single unit, the digestion capacity of the plant can be increased accordingly.

### *Use of Air-Lift for Raising Well Water*

The chief disadvantage usually quoted against the air-lift of water is low efficiency. The experience noted in this plant would indicate that its encouragement of corrosion of the piping is, in at least some cases, an unfavorable feature.

### *Alkalinity Tests for Efficiency of Elutriation of Sludge*

Tests at this plant established that with alkalinities in the neighborhood of 1,000 p.p.m. filtration of samples does not result in appreciable losses of volatile bicarbonates. It was further established that filtering of samples is a necessity for accurate results.

### *Summary of Tests on Digestion of Stored Elutriated Sludge, Recirculation of Elutriated Sludge, Detention and Short-Circuiting in Elutriation Tanks and Concentration of Elutriated Solids*

1. The resumption of digestion of an elutriated sludge in storage does not seem serious over a 2- or 3-day interval.

2. Recirculation of the stored solids in our elutriation tanks does not always result in a uniform reduction of dissolved compounds.

3. Our elutriation tanks, when half full of sludge, show a detention time of liquid travel through the tank of about 40 min. at present pumping rates.

4. There is a considerable loss of solids over the overflow weir when pumping into a tank with much stored sludge.

5. With several feet depth of sludge,

TABLE I. Summary of 1944 Operating Data, Greater Winnipeg Sanitary District

| Item | Average |
|---|---|
| Sewage received: | |
| Total M.G. (Imp.) | 7,425 |
| M.G.D. | 20.3 |
| Solids to effluent (tons) | 3,254 |
| Raw sludge to digesters (m.g. total, Imp.) | 14 |
| Tons dry solids per day | 17.4 |
| Sludge from digesters to filters (m.g. total, Imp.) | 10.3 |
| Sludge cake from plant: | |
| Million wet pounds (total) | 6.8 |
| Million dry pounds (total) | 2.04 |
| Ferric chloride used: | |
| Pounds total | 58,663 |
| Per cent, dry basis | 2.9 |
| Sludge gas: | |
| Produced (total cu. ft.) | 86,207,400 |
| For heating (total cu. ft.) | 31,582,900 |
| Wasted (total cu. ft.) | 54,625,500 |
| Plant influent: | |
| Temperature (F °) | 58 |
| Settleable solids (ml. per liter) | 9 |
| Suspended solids (p.p.m.) | 380 |
| pH | 7.5 |
| B.O.D. (p.p.m.) | 335 |
| Settling tank operation: | |
| Effluent settleable solids (ml. per liter) | 2.5 |
| Per cent removal | 71.6 |
| Effluent suspended solids (p.p.m.) | 180 |
| Per cent removal | 52.9 |
| Effluent B.O.D. (p.p.m.) | 240 |
| Per cent removal | 29.3 |
| Grit (cu. ft. per Imp. m.g.) | 1.4 |
| Raw sludge to digesters: | |
| pH | 5.7 |
| Per cent water | 91.0 |
| Per cent volatile | 70.7 |
| Digested sludge from digesters: | |
| pH | 7.4 |
| Per cent water | 93 |
| Per cent volatile | 52 |
| Digester temperatures (F °): | |
| No. 1 | 92 |
| No. 2 | 91 |
| No. 3 | 108 |
| No. 4 | 108 |
| Sludge gas: | |
| Produced daily (cu. ft.) | 236,500 |
| Wasted daily (cu. ft.) | 149,600 |
| Carbon dioxide (%) | 31.9 |
| Oxygen (%) | 0.2 |
| Methane (%) | 67.6 |
| Elutriated sludge: | |
| Sludge handled (total U.S. gal.) | 12,471,427 |
| Elutriated effluent (per cent dry solids) | 0.68 to 0.99 |
| Alkalinity (p.p.m.) | 870 to 980 |
| pH | 7.0 |
| Total days filters operated | 108 |
| Total cost of operation | $67,677.20 |

a 7 or 8 per cent solids content may be obtained in a few hours.

6. Results of the solids surveys would tend to support the practice of pumping into the elutriation tanks at separate times from sludge withdrawals. They would also indicate some maximum depth of sludge in the tanks of around 4 feet or less. If this depth does not represent a sufficient volume of sludge for an economical filter run, then perhaps a third tank would be of advantage as a concentration and storage tank.

Table I contains a summary of the 1944 operating data.

## Report of Operation of the Willow Run Bomber Plant, Detroit, Michigan, Sewage Treatment Plant for the Years 1943 and 1944

By N. Herda, *Supt.*

This plant was placed in operation on December 11, 1941. The sewage flow is brought to the treatment plant through a 24-in. gravity sewer, and the treatment works is of the activated sludge type.

During the early part of 1943 the plant reached the design load of sewage flow with a gradual increase to approximately a 50 per cent overload. This overload resulted in considerable carry-over of solids from the primary tanks, a supernatant liquor disposal problem and a further problem with wasting of the return activated sludge.

The plant provided for discharge of supernatant to about midway of the aeration tanks, or to the primary tanks. We tried the discharge of supernatant partially to the primary tanks and partially to the aeration tanks, both resulting in considerable trouble. Wasting the activated sludge to the primary tanks resulted in considerable carry-over to the aeration tanks, rising of sludge in the final tanks, and even with

**TABLE II. Summary of 1944 Operating Data of the Sewage Treatment Works of the Willow Run Bomber Plant**

| Item | Average | Item | Average |
|---|---|---|---|
| Sewage flow (m.g.d.) | 1.48 | Cu. ft. per lb. volatile solids added | 9.9 |
| Gal. per capita per day | 48.5 | Cu. ft. per lb. dry solids added | 7.5 |
| Suspended solids removal (%) | 95 | Activated sludge: | |
| 5-Day B.O.D. removal (%) | 90 | Aeration period (hr.) | 11 |
| Raw sludge: | | Dissolved oxygen, end of aeration (p.p.m.) | 2.6 |
| M.G. removed (total) | 1.68 | Sludge index | 561 |
| Per cent solids | 3.9 | Mixed liquor suspended solids (p.p.m.) | 1,139 |
| Per cent volatile solids | 74.3 | Mixed liquor settleable solids (per cent, 30 min.) | 52.9 |
| pH | 6.8 | Mixed liquor pH | 7.3 |
| Digested sludge: | | Suspended solids, return sludge (p.p.m.) | 3,779 |
| Gals. removed (total) | 128,911 | Return-sludge pH | 7.2 |
| Per cent solids | 2.1 | Suspended solids (p.p.m.): | |
| Per cent volatile solids | 73.7 | Raw | 104 |
| Digester No. 1, temperature (F. °) | 93 | Primary effluent | 80 |
| Digester No. 2, temperature (F. °) | 89 | Final effluent | 5 |
| pH, Digester No. 1 | 7.1 | 5-Day B.O.D. (p.p.m.): | |
| pH, Digester No. 2 | 7.2 | Raw | 125 |
| Filtering data: | | Primary effluent | 100 |
| Dry solids filtered (lb.) | 63,975 | Final effluent | 12 |
| Per cent CaO | 37.7 | Dissolved oxygen in final effluent (p.p.m.) | 1.5 |
| Per cent $FeCl_3$ | 0.63 | | |
| Lbs. solids per sq.ft. per hr. | 3.8 | | |
| Gas production: | | | |
| Cu. ft. per capita per day | 0.32 | | |

all mechanical aerators in operation, sufficient dissolved oxygen could not be maintained at the outlet end of the aeration tanks at all periods.

Corrective measures taken to control these conditions included: reducing the solids concentration in the mixed liquor, adding milk of lime to the primary tanks and aerators, and return of filtrate from the sludge filter to the inlet channel to the final tanks. These measures met with some degree of success.

Chlorination of the return sludge, and of the supernatant, was tried at dosages of 2 to 8 p.p.m., based on the return sludge flow. By the end of about ten days the carry-over was completely controlled, the final effluent was clear, and the sludge had good settling properties. After several months of applying chlorine to the waste activated sludge supernatant, it has not been too difficult to maintain the sludge in good condition.

Table II is a summary of the operating data for the year 1944.

## Report of Operation of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1945 *

By Ralph E. Fuhrman, *Supt.*

*Plant Overload*

The 1945 fiscal year ending June 30, 1945, saw the District of Columbia plant continue to receive increasing sewage flows to the extent of 11 per cent beyond its design capacity. The population overload is approximately 50 per cent.

*Night Soil Collections*

As in the past the discharge of night soil collected from the 782 privies in the District of Columbia was continued at the grit chamber. During the year 248,000 gal. were discharged from the 308 visits of the night soil truck. In addition to this quantity several loads were received from the circus performance in May, 1945.

*Sludge Treatment*

The increasing population load of the area served was further felt by the digestion tanks more than any other unit of the plant. Instead of the original allowance of 1.75 cu. ft. per capita during the year, the per capita volume dropped to about 1.10 cu. ft. The result has been highly critical operation of the digestion tanks.

In combination with the high gas production resulting from the high solids loads and the difficulty in maintaining flow through all the lines serving the tanks, some scum was lost through the relief covers in the tops of these tanks. While some scum has been dewatered directly with the sludge to alleviate this difficulty, lowering of a tank level prior to its receiving a raw solids load has been found quite effective. Fair control has resulted from this practice, though the need for additional digestion tanks is serious. At the end of the year preliminary approval had been received for the preparation of plans and specifications for four additional digestion tanks.

All digested sludge was elutriated prior to chemical conditioning for dewatering. The Potomac River is the source of wash water for this operation. Two stage washing was employed until March, 1945, at which time a temporary pipe connection was removed, allowing resumption of counter-current elutriation.

The sludge dewatering facilities did not maintain a high productive rate

* For previous extracts see This Journal, **14**, 5, 1,102 (Sept., 1942); **17**, 1, 132 (Jan., 1945) and **17**, 2, 364 (Mar., 1945).

throughout the year. The reasons for reduced production were manpower shortage and frequent lack of railroad gondola cars for shipment of sludge cake to the District of Columbia Penal Institutions at Lorton, Va. Because of vacancies in the plant operating staff, there were numerous occasions when there was insufficient crew to operate the dewatering-elutriation-digestion facilities for the production of sludge cake. The overall result of these handicaps is an accumulation of sludge in the digestion tanks, which sludge will have to be dewatered as early as conditions allow.

*Gas Engine Operation*

As in previous years the operation of the gas engine was curtailed during the coldest months in order to accommodate the Bellevue Housing Project for which the plant is the only source of gas for space heating. To aid with the digestion tank heating load the Navy Department brought to the plant a steam locomotive, oil fired, which was connected to heat the sludge digestion tanks in order to maintain digestion activity. This expedient has not been necessary in former years, but was probably necessary this year because of reduced gas production along with severely cold weather during the month of January.

During the year the engine jacket water cooler failed by external corrosion of the copper tubing. The plant effluent, which is settled sewage, was responsible. It is probable that this corrosion was greatly accelerated by the reduced loads on the engine already mentioned.

TABLE III. Summary of 1944 5 Operating Data, District of Columbia Sewage Treatment Plant

| Item | Average |
|---|---|
| Sewage flow (m.g.d.) | 144.1 |
| Approximate population served | 980,000 |
| Total cost for operation and maint. | $190,078 |
| Grit removed: | |
| Cu. yd. per day | 1.8 |
| Cu. ft. per m.g. | 0.9 |
| Per cent solids | 82.1 |
| Per cent volatile solids | 13.8 |
| Night soil handled at plant: | |
| Loads, total | 308 |
| Gallons, total | 247,960 |
| Suspended solids: | |
| Raw sewage (p.p.m.) | 151 |
| Effluent (p.p.m.) | 74 |
| Per cent removed | 51 |
| 5-Day B.O.D.: | |
| Raw sewage (p.p.m.) | 164 |
| Effluent (p.p.m.) | 116 |
| Per cent removed | 29.3 |
| Raw sludge: | |
| Per cent solids, range | 3.8–10.0 |
| Per cent fats in solids, range | 22.0–27.0 |
| Sludge digestion: | |
| Volatile solids added to digesters daily (dry lb.) | 62,631 |
| pH digested sludge | 7.3 |
| Temperature digesting sludge (F. °) | 95 |
| Per cent fats in digested solids | 8.9 |
| Sludge gas produced daily (cu. ft.) | 659,300 |
| Sludge gas per capita daily (cu. ft.) | 0.68 |
| Elutriated sludge: | |
| Per cent solids | 7.3 |
| Per cent volatile matter in solids | 47.6 |
| Ratio wash water to sludge volume | 1.5 |
| Alkalinity of digested sludge (p.p.m.) | 3,010 |
| Alkalinity of elutriated sludge (p.p.m.) | 865 |
| Analyses of elutriate: | |
| Suspended solids, range (p.p.m.) | 781 to 3,010 |
| Alkalinity, range (p.p.m.) | 621 to 1,940 |
| 5-Day B.O.D., range (p.p.m.) | 258 to 629 |
| Sludge dewatering: | |
| Days of dewatering per month | 15.0 |
| Filter hours per month | 327.4 |
| Per cent solids in cake | 27.8 |
| Yield of solids (lb. per sq. ft. per hr.) | 6.8 |
| Per cent of ferric chloride | 3.51 |

*Laboratory Activities*

Weekly composite samples of fresh solids, digested sludge and scum were tested for chloroform soluble material (fats). For the last two months parallel determinations were made with petroleum ether in preparation for the change to this solvent by the new Standard Methods.

Chemicals used at the plant were assayed to determine their strength, which is the basis of payment. Occasional tests were made on the lubricants used throughout the plant. Boiler water was analyzed regularly to determine the chemical dosage necessary in its treatment. Sludge gas is analyzed for chemical constituents and fuel value.

*Mechanical Repairs*

Most of the sludge pumps were fitted with new cylinders, pistons, rods, beams and bearings. Failure in the sludge pump reduction units was reduced by installation of a 28:1 gear ratio train in place of the former 30:1 ratio. Greater strength in the intermediate gear shaft was thereby obtained.

*Use of Sludge Cake*

Sludge cake shipped by the plant to the D.C. Penal Institutions is applied there directly to the soil or stored and applied later. While the original plan of sludge disposal there contemplated its use to replace in part, at least, commercial fertilizer purchases by the institution, the institution officials have not shared this view and consider the sludge of very low fertilizing value. Since the anticipated value has not been realized, the costs incurred by the necessary operation are properly charged as a sewage treatment function. (*Abstractor's note:* If digested primary sludges were accepted as soil conditioners and not as competitors of commercial fertilizers, such differences of opinion would not occur.)

Operation data for the year ending June 30, 1945 are summarized in Table III.

## Thirteenth Annual Report of the Green Bay, Wisconsin, Metropolitan Sewerage District Commission for the Year Ending March 31, 1945 *

By George Martin, *Supt.*

This being the thirteenth annual report it brings up to date the records of the Green Bay Metropolitan Sewerage District which came into being on December 4, 1931. In addition thereto, it covers the tenth year of sewage works operation. During these ten years that the sewage from this area has been collected and treated, much has been accomplished in pollution abatement but much still remains to be done. No longer are there great sewage sludge deposits in the East and Fox Rivers. These no doubt are gone forever and with their disappearance goes much of the disagreeable odor that is associated with the disintegration of human wastes. However some untreated domestic and industrial liquid waste and solids still enter the East and Fox Rivers at times of heavy rain and, while the strength of this storm sewage is not great, it is not a desirable condition and is one that can only be eliminated by the separation of the sewer system. Just this year the City of Green Bay, which is charged with the responsibility of installing and maintaining the sewer system in 95 per cent of the Green Bay Metropolitan Sewerage Dis-

* For previous extracts see This Journal, **13**, 3, 587 (1941); **17**, 1, 130 (1945).

TABLE IV.—Summary of 1944–45 Operating Data, Green Bay (Wis.) Metropolitan Sewerage District

| Item | Average |
|---|---|
| Sewage flow (m.g.d.) | 7.67 |
| Storm water by-passed, total (m.g.) | 454.05 |
| Raw sludge, total dry solids (lb.) | 3,366,351 |
| Dry solids (lb. per day) | 9,223 |
| Volatile dry solids, total (lb.) | 2,216,751 |
| Volatile dry solids (lbs. daily) | 6,155 |
| Sludge gas, cu. ft. daily | 68,910 |
| Sludge gas consumed (cu. ft. daily) | 64,679 |
| Hydrogen sulfide in sludge gas (grains per 100 cu. ft.): | |
| Max. | 35 |
| Min. | 4 |
| Digested sludge withdrawn: | |
| Wet sludge, total (cu. yds.) | 14,984 |
| Per cent moisture: | |
| Max. | 96 |
| Min. | 81 |
| Volatile matter (%): | |
| Max. | 68 |
| Min. | 34 |
| 5-Day B.O.D. (p.p.m.): | |
| Influent | 284 |
| Final effluent | 212 |
| Per cent reduction | 24.7 |
| Suspended solids (p.p.m.): | |
| Influent | 226 |
| Final effluent | 104 |
| Per cent reduction | 55 |
| Screenings (cu. ft. daily) | 17 |
| Grit (cu. ft. daily) | 44 |
| Chlorine: | |
| Total lb. for 4 months | 53,663 |
| Max. p.p.m. fed | 17 |
| Electrical energy (kw. hr.): | |
| Produced by plant, total | 793,541 |
| Consumed, total | 868,362 |
| Operating costs: | |
| Total for year | $35,334.20 |
| Per m.g. | $10.85 |

trict, started its storm sewer separation program. Not enough was accomplished this year to be noticed, as not even the first project was completed, but it was a start that shows all indications of progressing at an ever increasing rate. Undoubtedly, in a relatively short while, much will be accomplished in not only relieving the pollution load on the two rivers and Bay but in entirely eliminating basement flooding in the area served.

The industrial pollutional load in the East and South Rivers, which is almost entirely paper mill waste and mostly waste sulfite liquor, is terrific. For over five years the sulfite paper mills have exerted a concentrated effort to find a solution for their problem, which to date has shown progress but no definite solution. If and when the paper mill problems are solved and their pollutional load is reduced a reasonable amount, then it will behoove the municipalities in the Fox River Valley to increase their treatment facilities at least to the extent of intermediate treatment. Rome was not built in a day, neither is the Fox River Valley overcoming their sewage problems overnight, but progress is being made and every day more people and industries realize their ever increasing responsibilities so far as pollution abatement is concerned and more and more effort is directed to the final aim of restoring the waters to a reasonable year-round state of purity. Then and only then can it be said that the sanitary problems of this area have been solved.

As to the results of sewage treatment in the Green Bay Metropolitan Sewerage District, they have been as good as can be expected of a primary treatment plant. No particularly unusual problems presented themselves but plant maintenance was on the increase. This, of course, is to be expected as 10 years of sewage service is wearing on any plant and it can be said that the maintenance and repair problems are just beginning. Taking all things into consideration, the management has the feeling that the District had a successful year.

A summary of plant operating data for the year ending March 31, 1945 is given in Table IV.

# Annual Report for the Year 1944 of the Bureau of Sewers of the City of Worcester, Mass.

By John H. Brooks, Jr., *Superintendent* *

*Maintenance of System*

The expenditures for the upkeep and operation of the public sewer system are increasing. While the annual increments made to the mileage of sewers is of some moment, the chief factor and contributing agency is the deterioration caused by the ravages of time and ordinary wear and tear. The early sewers in the Worcester system date from the early 1860's.

*Trickling Filter Operation*

The trickling filters are in poor condition as a result of the character of the influent during the past 20 months and will not regain satisfactory or normal operating efficiency until the quantity of acid discharged into the sewage is greatly reduced. Following this, the filters will have to clear themselves of all clogging material by

* For previous extracts see This Journal, **10**, 6, 1,075 (1938); **13**, 6, 1,244 (1941); **17**, 2, 357 (1945); **17**, 5, 1,012 (1945).

TABLE V. Summary of 1944 Operating Data, Worcester, Mass.

| Item | Average |
|---|---|
| Estimated population connected | 185,000 |
| Sewage flow (m.g.d.) | 22.04 |
| Max. | 55.23 |
| Min. | 11.95 |
| Total net expenditures of department | $312,662.07 |
| Cost of sewage treatment, total | $54,287.39 |
| Per m.g. sewage* | $6.73 |
| Valuation of sewage treatment works | $4,149,000.00 |
| Valuation of all properties and supplies | $19,326,893.88 |
| Total man-hours of operation, entire dept., yr. | 224,809 |
| Catch basin cleaning: | |
| No. cleaned | 5,554 |
| Yards of material removed | 10,172 |
| Hours of work | 3,040 |
| Trucking hours | 6,040 |
| Plant grit chamber: | |
| Total cu. yds. material removed | 839.1 |
| Cu. ft. per m.g. | 2.81 |
| Total tons | 881 |
| Cost of removal per cu. yd. | $0.35 |
| Screenings: | |
| Total cu. ft. | 11,558 |
| Cu. ft. per day | 31.6 |
| Cu. ft. per m.g. | 1.43 |
| Total tons | 387.2 |
| Cost of removal per cu. ft. (cents) | 10.3 |
| Imhoff tanks: | |
| Detention (hr.) | 2.8 |
| Skimmings removed, total (cu. ft.) | 3,567 |
| M.G. of wet sludge, total | 18.42 |
| Sludge solids (%) | 7.43 |
| pH of sludge | 6.5 |
| Volatile matter in sludge (%) | 45.9 |
| Iron in sludge (%) | 3.61 |
| Trickling filter operation: | |
| M.G. treated per acre per day | 1.51 |
| Nozzles cleaned: | |
| Total | 22,480 |
| Per day | 61 |
| Secondary settling tank operation: | |
| Detention (hr.) | 2.2 |
| Gal. wet sludge | 6,968,900 |
| Per cent solids in wet sludge | 3.5 |
| pH of sludge | 6.9 |
| Per cent dry volatile solids | 47.3 |
| Per cent iron in sludge | 8.58 |
| Suspended solids (p.p.m.): | |
| Raw sewage | 239 |
| Imhoff tank effluent | 108 |
| Trickling filter effluent | 116 |
| Secondary tank effluent | 80 |
| Per cent overall removal | 66.5 |
| 5-Day B.O.D. (p.p.m.): | |
| Raw sewage | 174 |
| Imhoff tank effluent | 123 |
| Trickling filter effluent | 54 |
| Secondary tank effluent | 51 |
| Per cent overall removal | 70.5 |
| Relative stability (%): | |
| Trickling filter effluent | 41 |
| Secondary tank effluent | 41 |
| Dried Sludge removed from drying beds: | |
| Cu. yds. sludge removed, total | 18,217 |
| Cost of removal per cu. yd. (cents) | 68.2 |

* Per capita cost: 29.4 cents.

proper operation accompanied by favorable warm atmospheric conditions.

Pooling of the filters has occurred throughout the entire year; tests have indicated that the greater part of this difficulty is due to surface conditions of the filters. Due to the character of the influent, this condition has not been remedied despite the efforts made for its elimination.

*Condition of Sludge*

Despite the fact that the pH of the Imhoff tank sludge was 6.5, the sludge appeared to be well digested, a result similar to that in 1943. Owing to slot clogging difficulty, the level of the top sludge has been kept lower than usual. It is believed that the higher volatile matter content of the December sludge was due to the character of sludge drawn from two tanks during the month. It is possible that heavier sludge in the corners caused movement of sludge from the centers of the hoppers and that this sludge was not as thoroughly digested as usual.

*A Closing Comment*

Sewage treatment is one function of municipality operation which receives but little consideration by the taxpayer or the general public. The usual conception of the matter is that it is one of expense. Almost no thought is given to the fact that some 3 m.g.d. of industrial waste liquors, together with the wastes from the plumbing systems of residences, apartments, stores and offices, are disposed of in an unobjectionable manner for the expenditure of thirty cents per person for an entire year. The work goes on 24 hours each day and 365 days each year and is responsible for the solution of a health problem affecting every individual living or working in the city of Worcester.

Table V is a summary of the 1944 operating data.

## TIPS AND QUIPS

### Sewage Farming at Tucson

Sewage farming as practiced commonly in the Southwest, is typified by the procedure at Tucson, Ariz. The entire sewage flow, averaging about 4 m.g.d., is used to irrigate about 300 acres of city-owned land.

The sewage is given conventional primary treatment by separate sedimentation and digestion units before discharge to the irrigation ditches. Two Scott-Darcey units located on the main outfalls from the city provide chlorinated iron solution for the control of sulfides during flow to the plant. Operation of the digesters here is simplified by the weather, in that the air is so dry that supernatant can be drawn to lagoons where it seeps and evaporates away almost overnight.

Flow of the clarified sewage to the field in cultivation is by gravity. Crops of oats, barley and ensilage are rotated on the land, a force of six to eight men being employed in the operation of the treatment plant and of the farm. Gross income from the crops is $22,000 to $28,000 per year, yielding a net profit of $3,000 to $5,000 after the deduction of all expenses. Unimproved land of the character farmed at Tucson is said to be valued at only $8 to $10 per acre.

Phil T. Martin, former Federation director, is city manager at Tucson. Sewage works operation is under the supervision of Merrill Biggs and John F. Rauscher of the city water department.

### Ozonation of Sewage

Ozonation as a sewage treatment device is to receive a trial on a plant scale basis in a municipal plant being

built (June, 1946) at Kelso, Wash. The installation is being made on a conditional basis by "Amozone of Oregon," a corporation which has been actively promoting the process in the Northwest, where the very low prevailing power rates are most favorable to ozone generation at low costs.

The Kelso installation has optimistically been located one block from the main street of the town, on a lot adjacent to an apartment building. The plant units, comprising a comminutor, ozone generation equipment, facilities for applying ozone and copperas, flocculation channels and hopper-bottom sedimentation tanks, are completely housed. Ozone is to be applied to the sewage for disinfection after chemical precipitation and settling and it is intended to oxidize the sludge produced by ozonation, to the end that it may be re-used as a coagulant.

Feeling that the Amozone Process is being exploited without adequate preliminary development and to offset promotional interference in cities that have already begun to plan conventional sewage treatment works, the Pacific Northwest Sewage Works Assn. has distributed the report of a special committee to the officials of all incorporated municipalities in Washington, Oregon and Idaho. This report concludes with the recommendation "to discourage cities from entertaining proposals which claim ozonation as the principal means of sewage treatment and, particularly, to advise officials against the making of any contract for a system of sewage treatment and disposal which is not accepted by State health officers on the basis of adequate design and as being of a type which experience has shown to be reasonable in cost and successful operation."

While there is considerable published material on ozonation for the disinfection of water, there is little to be found on the application of ozone for the treatment of sewage. The only authoritative reference as yet located by the writer is a paper by Prof. Frank R. Theroux, as published in Bulletin 74 (1936) of the Michigan Experiment Station. This work was done on a small pilot plant scale and the results were sufficiently interesting to justify the author's recommendation that more complete research on a larger scale be undertaken. Other laboratory research has been conducted in Pennsylvania and results of a few experiments made at a New Jersey institutional plant are reported in the company's literature.

Regardless of the possible merits of the process, however, there is far too little information available to warrant its general exploitation for municipal installations at this time. The Pacific Northwest Sewage Works Assn. has undoubtedly rendered a notable service by the precautionary advice that has been distributed in the states it includes.

Operating results and cost data from the Kelso plant will be anticipated with interest. David B. Charlton, Consulting Chemist, Portland, Ore., has been engaged to supervise and correlate the laboratory data.

## Mississippi Pollution Legislation

Enactment by the Mississippi Legislature in the 1946 regular session of Senate Bill 208 has given that state a stream pollution control law that has been badly needed. The law is somewhat different than those operating in most other states in that the administrative authority is vested in the State Game and Fish Commission, which body is authorized to "employ a qualified engineer and such other help and expert, professional and technical services as it deems necessary to carry on the purposes of the act. . . ."

Promptly upon passage of the Act, H. R. Covert, formerly Sanitary Engineer of the Gulfport Army Air Field, was appointed as the Sanitary Engineer for the Fish and Game Commis-

sion. Rules and regulations have already been adopted to control pollution by sewage and industrial wastes, with stream water quality criteria (based on conditions 1,000 ft. below the waste outlet) being established generally as follows:

1. No visible floating solids, scum, oil, grease or sleek.
2. Average pH within the limits of 6.0 to 8.4.
3. Maximum increase in salt concentration of 1,000 p.p.m. as NaCl.
4. Average dissolved oxygen to be 3.0 p.p.m. or greater. No single sample less than 2.5 p.p.m.
5. No poisons or other substances deleterious to fish or wildlife.
6. No substances producing distinct foreign tastes in fish.

An entire section of the regulations is devoted to the control of oil field wastes, which are a major problem in Mississippi. The commission is required to review plans for all sewage and industrial waste treatment works and to issue permits for such plants to be operated. Authority to control operation is also given.

## DDT and Digestion

The effect of DDT on sludge digestion, where humus sludge is handled from filters that have been treated for fly control, is the subject of a question raised by Santary Engineer H. R. Covert of the Gulfport (Miss.) Army Air Field after he read the articles by Brothers and Carollo in the March issue of THIS JOURNAL. Reference of the question to Mr. Brothers brought the following comments concerning extraneous effects on the Camp Fannin plant of the DDT experiments conducted there:

"I relied on our camp sanitary engineer to keep me informed as to any harmful reactions during the tests and at no time could anything out of the ordinary be noted. After the work was completed, we examined the consolidated records for the summer and no variation could be noted during the periods covered by the tests. We had thought that at the time of dosing some slight action might occur which would not show up at the time but which would be revealed if studied in conjunction with the yearly records. No variation from the normal was noted in any part of the plant."

## Activated Sludge With Fins

Killifish are a variety of small fish that are able to live in either fresh or sea water. According to Dr. L. R. Setter, Principal Sanitary Chemist of the New York City Department of Public Works, killifish seem to find a particularly favorable environment in the aeration and final settling tanks of the Modified Aeration Process at New

FIGURE 1.—Activated sludge at the Jamaica sewage treatment plant, New York City.

York's Jamaica plant. A few typical specimens are shown in Figure 1.

Oxygen concentrations of 0.5 to 3.0 p.p.m. in the aeration tanks, diminishing to only traces in the final settling tanks, appeared to be quite adequate for the killifish. Several bushels of the fish were "inactivated," however, when the mixed liquor solids were increased early in 1946 to conventional activated sludge concentrations.

## Peoria Pioneers

The Kraus-Longley team at the Greater Peoria (Ill.) Sanitary and Sewage Disposal District is a mighty hard one to beat when it comes to originality of ideas and ability to develop them. Identified more completely as J. R. Longley, District Engineer, and L. S. Kraus, Chemist, the successfulness of this pair is proved by the fact that they are handling a population equivalent averaging 300,000 to 400,000 in an activated sludge plant designed for 200,000 population and, withal, producing an effluent of excellent quality. The *Corner* was privileged to visit this plant last June and has been marveling ever since at what it saw.

The procedure that has been primarily responsible for the ability of this plant to perform so efficiently under the extraordinary overload is the activated sludge conditioning process (using digested sludge and supernatant as conditioning agents), as reported by Kraus in the November, 1945 issue of THIS JOURNAL. There is no doubt about it—the method does control bulking in a heavily worked activated sludge; it produces a high grade effluent that could not be achieved in the same plant by any of the "conventional" procedures and it eliminates completely the digester supernatant disposal problem.

Another improvement in this plant that has contributed to its ability to handle excessive loads is the simple revision of the outlet weirs at the original Dorr cross-flow traction-type final settling tanks. Again defying conventional practice, the new launder troughs and weirs were located just behind the *inlet* baffles with remarkable results. These tanks now give excellent efficiency at loadings (on a mixed liquor basis) up to 1,800 gal. per sq. ft. per day. Mr. Longley has consented to develop an article on this work for publication in THIS JOURNAL; the idea will undoubtedly find wide application in many of the older plants.

The current project of this ingenious team is an interesting procedure for waste activated sludge concentration, in which advantage is taken of the heretofore vexing tendency of nitrified activated sludge to rise to the surface of settling or concentration tanks. Mr. Kraus describes the process as "concentration by levitation" and it was yielding a concentrated sludge of about 8 per cent solids at the time of our visit! Readers of the JOURNAL may also look forward to the conclusions on this study when, in the opinion of Mr. Kraus, it is "ready" to report. While he has no inhibitions when it comes to undertaking something new and relatively untried, he is commendably conservative in withholding conclusions until all findings are confirmed by long-term data.

The Peoria team has not been remiss in taking advantage of work done elsewhere in addition to their own new projects. A 10-year period of operation of the gas engines in use for power generation and air compression has just been completed. A cost recapitulation for this period shows that the engines have saved about $350,000 in purchased power during the ten years, after allowing for all fixed and operating charges. The engines paid for themselves in 2½ years!

And that is not all. Mr. Longley has somehow found the time during the past two years to serve the interests of the Illinois Association of Sanitary Districts, an organization of the trus-

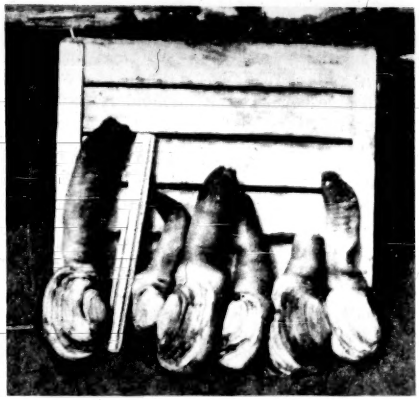

FIGURE 2.—The geo-duck clam of Puget Sound. Note ruler showing size.

tees of the 25 sanitary districts in Illinois. In this association the trustees have associated with them the attorneys and technicians and much has been contributed in the past to the cause of sewage treatment in the state. After two years of limited wartime activity, the association was called together by Longley (who now serves as Secretary) and others to the end that one of its most successful meetings was held at Peoria in June of this year.

### Geo-Ducks?

When the Pacific Northwest Sewage Works Assn. met at Gearhart, Ore., last spring, association President C. M. Howard extended to us an invitation to go on a geo-duck expedition at the first opportunity. Visions of boyhood "snipe hunts" must have made our skepticism rather apparent, as Mr. Howard hastened to give assurance that the geo-duck is otherwise known as the Paul Bunyan clam, an inhabitant of the beaches of Puget Sound.

Upon our return from Oregon, Mr. Howard was kind enough to furnish proof (Figure 2) that geo-ducks are actually hunted and that their capture must be a fascinating sport. If there must be a reason for presenting this item in a sewage works publication, it is suggested that this knowledge may be of value to any midwesterner who might encounter a geo-duck while patrolling Puget Sound on a pollution survey!

### And All for a Stamped, Self-Addressed Envelope!

A number of newspapers recently carried the following item in the syndicated column of a medical "authority." The query and answer given by the writer of the column are captioned "The Best Fertilizer":

"We have a vegetable garden near the city sewage disposal plant, and this garden was fertilized with sludge this spring. Will it endanger our health to eat vegetables from the garden this summer? W. R. F.

"Answer—No. In fact there is no good reason why the sludge from all sewage disposal plants should not be used as fertilizer—it is the best of all fertilizers. The natural fermentation process destroys any disease germs in the sewage."

One sewage works technician puts it mildly when he suggests that the good doctor "is covering quite a lot of territory." Even the most enthusiastic

sewage works operator would not give such a forthright recommendation to the use of sludge for fertilizer—either in regard to its value as a plant food or to its freedom from disease germs. It would seem that a complimentary copy of the Federation's new Manual of Practice No. 2 might be a worthy addition to a certain medical library.

*Note:* If any of the readers of this column are troubled with dizzy spells, adenoids, eczema, trichinosis, athlete's foot or Rocky Mountain spotted fever, please do *not* request our advice!

V.
19

# Editorial

## INDUSTRIAL WASTES ACTIVITY IN THE FEDERATION

The accelerated interest in industrial waste pollution problems at this time spotlights a responsibility that the Federation assumes in the first objective stated in its Constitution, to wit:

"The objects of this Federation shall be: The advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage *and industrial wastes* . . . ."*

Until recently, the Federation met its responsibility to those concerned primarily with industrial wastes problems only to the extent that a relatively small part of the JOURNAL was devoted to papers on industrial waste topics. The limited quantity of material thus published was due to the fact that very little of it was available and not to editorial discrimination. It appeared that industrial wastes technicians (*a*) were restricted by company policies from publishing results of their work, (*b*) they did not consider it worth while to exchange information beyond the limits of their own industry or (*c*) they failed to appreciate the advantages of the Federation and its JOURNAL as the dispensary of information of common value. If the latter was a deterrent, it must be admitted that the Federation has not heretofore made a special effort to inform industrialists as to what it can offer them. This deficiency is now being rectified.

There are a number of strong arguments favoring the Federation as the professional clearing house for industrial wastes knowledge. Among the foremost of these are:

1. The most practical and economical solution to a large percentage of industrial waste disposal problems is by discharge to municipal sewage treatment plants that have been planned and designed to handle such combined wastes. The Federation now represents the consulting engineers and operators who build and attend these plants; it therefore offers a common ground upon which these groups can meet with representatives of industry and reach the understanding that is essential to the development of joint solutions of their problems.

2. The Federation is the acknowledged medium for exchange of information on stream standards, pollution survey methods and on the interpretation of stream survey data and results. This material is of fundamental importance in the evaluation and solution of industrial waste problems. Sewage and most industrial wastes are similar in their effects upon the stream—should not their control be along parallel lines?

3. Federal, interstate, state and local stream pollution control agencies are universally represented in the membership of the Federation. Here is an opportunity for the industrial representative to meet with pollution control authorities and to exchange points of view to mutual advantage. It is only through complete understanding that pollution control laws and regulations can be administered adequately, practically and fairly. There may be some short-sighted representatives of industry who will deny this claimed advantage, feeling that industry should unite separately and not cooperate with pollution control agencies. Such clashing interests, however, could never be so constructive to a final solution as a combined approach to the acknowledged problem.

* Italics ours—Ed

4. Many organic industrial wastes are amenable to treatment by conventional methods of sewage treatment. Sewage works technicians are specialists in the stabilization of organic wastes and industry can benefit tremendously from their experience and knowledge. Likewise, industrial technicians are constantly proving their resourcefulness and ingenuity, so that both groups will gain by their contact and acquaintanceship.

About three years ago, the Board of Control of the Federation, realizing that the activities of the organization were not developing with respect to its obligations to industrial wastes interests, took steps to correct this situation. At the Sixteenth Annual Meeting a special Industrial Wastes Committee was authorized "for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial wastes problems."

This committee, headed by Dr. F. W. Mohlman, immediately began to encourage the submission of industrial wastes papers for publication in the JOURNAL. As a result, the quantity of such material increased from an average of 65 pages per year in the period 1936–43 to an average of 96 pages per year since 1943. The annual volume should be much greater, of course, but a start has been made.

At the Nineteenth Annual Meeting held last October in Toronto, Dr. Mohlman announced plans to enlarge his committee and to initiate a continuous series of industrial waste articles to be authored by the committee members. This program is certainly a move in the right direction.

The technical programs of the Federation meetings at Pittsburgh in 1944 and at Toronto in 1946 each included an entire session devoted to industrial waste papers. The trend in these programs will be to give more and more time to this phase of the pollution control problem. Eventually, it may prove desirable to establish an Industrial Wastes Section in the Federation —a development which will be expedited by the affiliation of a sufficient number of industrial waste technicians to make the action feasible.

The Federation's Committee on Standard Methods of Sewage Analysis, headed by Dr. W. D. Hatfield, has also recognized the trend of the times, and has created a new Subcommittee on Methods of Industrial Wastes Analysis. Work along these lines has been sadly lacking, but the path toward fulfillment of the need has now been opened.

In order for the Federation to serve industrial wastes interests, however, it is essential that industrial technicians make themselves available for participation in Federation functions. They must take part in the programs of meetings of the Federation and its Member Associations; they must contribute material for publication in the JOURNAL; they must be willing to serve on appropriate committees and otherwise to make themselves a part of the Federation's structure.

At this writing, a prospective Member Association of the Federation has tentatively adopted the name "Virginia Industrial Wastes and Sewage Works Association." This is indeed a progressive step, in line with the fundamental objectives of the Federation.

There are many technicians in industry who are not aware of the Federation and its aims, and who would gladly take advantage of the facilities we offer. Let us all make it a personal responsibility to see that these people are fully informed and invited to join in the growing movement to abate pollution of streams by the provision of works that accomplish this end most effectively and economically.

W. H. WISELY

# Proceedings of Member Associations

## ALABAMA WATER AND SEWAGE GROUP ORGANIZES

As the result of efforts originating in 1937 and interrupted by the war, the First Alabama Water and Sewage Short Course was held at Alabama Polytechnic Institute on May 22–25, 1946, with a final registration of 85. The course was sponsored by the University of Alabama, the Alabama Polytechnic Institute and the State Department of Public Health; future short courses will be alternated between the two schools; the 1947 conference has been scheduled to be held at the state university next spring.

The registration at the Auburn conference was estimated to represent about 20 per cent of all water and sewage works operators in the state. A diversified program was presented, featuring such contributors as T. H. Milford, A. W. Beck and C. W. White of the Alabama Department of Public Health; Prof. Gilbert H. Dunstan of the University of Alabama (who served as co-chairman of the short course with Alex O. Taylor of the Alabama Polytechnic Institute); W. H. Weir, N. M. DeJarnette, G. R. Frith and W. L. Avrett of the Georgia Department of Health; Prof. A. P. Black of the University of Florida; Malcolm Pirnie, Consulting Engineer, New York City; L. H. Enslow, Editor of *Water and Sewage Works* and others. Papers covering broad subjects of general interest were emphasized at this first short course. Future programs will be classified into elementary and advanced groups, with at least half of the lectures to be on specific operation topics.

The short course technical program was concluded with a business meeting at which the Alabama Water and Sewage Association was created. Temporary officers were elected and committees appointed to complete the organization by developing a constitution and by-laws. The officers and committees were authorized to draft articles of organization that will comply with the requirements of the Federation of Sewage Works Associations, with the aim of affiliating with that international organization as a Member Association probably in 1947.

Officers of the new association, to serve until the 1947 meeting, are: W. W. Pointer of Troy, *President*; W. H. H. Putnam of Birmingham, *Vice-President*; Alex O. Taylor of Auburn, *Secretary*, and Prof. G. H. Dunstan of University, *Treasurer*. A. N. Beck of the State Department of Public Health was appointed Editor, to be assisted by Secretary Taylor in producing a periodical news bulletin for distribution to the membership.

The enthusiasm and interest with which the short course and new association were initiated presages a productive and successful future for these activities in Alabama. Officials of the state educational institutions and department of health are to be commended for their co-operative development of the program.

## FLORIDA SEWAGE WORKS ASSOCIATION

Fourth Annual Meeting
Gainesville, Florida, June 5–7, 1946

The Fourth Annual Meeting of the Florida Sewage Works Association was held at the University of Florida Campus at Gainesville on June 5–7, 1946.

The meeting was a part of the An-

nual Florida Short Course in Water and Sewage Treatment, of which the FSWA is a joint sponsor with the Florida Section of AWWA, the Florida State Board of Health and the Florida Water and Sewage Works Operators Assn. The total registration for the course was 114.

The principle underlying the development of the short course program is to train the operator to do a better job by instructing him in standard methods and giving him actual practice in laboratory procedure. It was the concensus of opinion that future short course programs should run five days instead of three, giving more time to operators' examinations; more and longer periods devoted to laboratory work; and that the program should include intensive study on the subjects to be covered in the examinations for operators' licenses.

Eighteen manufacturers' representatives were present for the course, six of whom served as lecturers. These men not only made instructive contributions during the discussions but also acted as consultants to operators who had special operation problems.

An interesting description of the new experimental pilot plant being constructed by the Industrial and Engineering Experiment Station at the University of Florida was given by Prof. D. L. Emerson, and was followed by an inspection trip through the plant.

Papers presented during the technical sessions were:

"Care and Maintenance of Electrical Equipment," by W. J. Siebert.

"Present Trends in Sewage and Water Treatment," by W. H. Wisely.

"Operating Problems in Sewage Disposal: Multiple Treatment Units in Sewage Plant Design," by Kenneth Morkert.

"Hazards in Sewage Treatment Plant Operation," by W. H. Wisely.

"Interest and Responsibility of the Water and Sewage Plant Operator in the Extent of Stream Pollution," by J. G. Patterson and P. M. Teeple.

"Grease Removal," by L. H. Scott.

"Care, Maintenance and Operation of Sewage and Sludge Pumps," by S. E. Kappe.

"Industrial Waste and By-Products Recovery," by R. R. McNary.

"Progress Report on Intermittent Sand Filter Investigation," by D. L. Emerson.

"Operation of High Rate Trickling Filters," by Wayne Kivell.

"Sludge Digestion Problems," by C. F. Garland.

At the annual business meeting, Benjamin F. Borden, Jr., Consulting Engineer of Smith and Gillespie, Jacksonville, was elected President of the Florida Sewage Works Association for 1946-47; Albert L. McGregor of Boca Raton was elected Vice-President and J. R. Hoy of the Wallace and Tiernan Co., Jacksonville, was re-elected Secretary-Treasurer.

J. R. Hoy,
*Secretary-Treasurer*

## NEW JERSEY SEWAGE WORKS ASSOCIATION

### Thirty-First Annual Meeting
### Trenton, New Jersey, March 20–22, 1946

The Thirty-first Annual Meeting of the New Jersey Sewage Works Association was held in Trenton on March 20–22, 1946, in co-operation with the Bureau of Engineering and Sanitation of the New Jersey State Department of Health. A total of 330 members and guests attended. This was the second largest registration in history, being surpassed only by the 25th Anniversary meeting. Edward P. Decher, Second Vice-President, presided over the tech-

nical sessions in the absence of President John H. Simmerman.

The meeting opened on Wednesday with registration, inspection of exhibits and a smoker.

The technical sessions on Thursday, March 21, included the following papers:

"The Use of DDT as an Insecticide," by Herman L. Fellton, Sanitarian, Malaria Control in War Areas, USPHS; Leslie West, Chief Engineer, Joint Meeting of Essex and Union Counties Sewage Treatment Plant, Elizabeth, N. J. and Dr. E. J. Hansen, N. J. Agricultural Experiment Station, Department of Entomology, New Brunswick, N. J.

"Proposed Short Courses for Sewage Treatment Plant Operators," by Prof. H. N. Lendall, Head of Civil Engineering at Rutgers University, New Brunswick.

"Comprehensive Planning as an Aid to Efficient Sewerage Projects," by T. Ledyard Blakeman, Chief of the Bureau of Planning, N. J. State Department of Economic Development.

"The Federal Works Agency's Aid to Municipalities in Preparing Plans for Public Works," by William D. Jones, Division Engineer of the Federal Works Agency.

"Financing of Sewerage Projects," by Walter R. Darby, Director of Local Government, N. J. State Department of Taxation and Finance.

"Operating Problems Encountered at City Island Plant," by George W. Cameron, Superintendent of City Island Sewage Treatment Plant, Atlantic City Sewerage Company in Atlantic City, N. J.

"Fundamentals of Biological Oxidation Clarification," by John W. Hood, Superintendent of the Ridgewood, N. J., sewage treatment plant.

"Operation of High Rate Filters at Camp Kilmer," by Clyde J. Shepherd, Sanitary Engineer at Camp Kilmer, N. J.

A highlight of the Thursday session was the Testimonial to John R. Downes, tendered in behalf of the NJSWA by Francis S. Friel, Consulting Engineer and Vice-President of the Federation of Sewage Works Associations.

Among Mr. Downes' professional accomplishments, Mr. Friel cited the following: introduced the use of alum in sludge drying on beds; instrumental in the establishment of sewage research division at Rutgers University, introduced and patented the floating cover for sludge digestion, first operator to use sludge gas for power, first to employ spray drying of sewage sludge.

Mr. Downes was one of the founders of the NJSWA, acting as its first president, and from 1922 to 1945 served as its secretary. In recognition of his service to the NJSWA and to the profession, Mr. Downes was presented with the Kenneth Allen Award of the Federation, a scroll, a watch and a billfold.

The annual dinner and entertainment, sponsored by the Water and Sewage Works Manufacturers Association, was attended by over 250 persons and was an outstanding success.

The Friday technical sessions included the following papers:

"The Effect of Food Wastes on Sewers and Sewage Treatment Processes," by Morris Cohn, Editor of *Sewage Works Engineering* and Sanitary Engineer of the City of Schenectady, New York; Dr. Willem Rudolfs, Chief of the Department of Water and Sewage Research of the N. J. Experiment Station at New Brunswick and William A. Bode, Columbia University, representing the Izaak Walton League of America, Inc.

"Experiences in Financing Sewerage Projects," by Henry W. Peterson, President of the Woodbury, N. J., Council and Secretary of the South Jersey Port Commission and Chester W. Paulus, Mayor of New Brunswick.

"The Procurement of Surplus Property for Municipal Sewerage Needs,"

by M. L. Smith, Sanitarian to the Office of Surplus Property Utilization of the USPHS.

At the annual business meeting on Friday the "Club Room" type of entertainment was discussed. The membership voted unanimously for its discontinuation at future meetings.

Officers elected to serve during 1946-47 were:

*President*—Louis J. Fontenelli, Rahway
*First Vice-President*—Leslie E. West, Elizabeth
*Second Vice-President*—John Struss, North Wildwood
*Secretary-Treasurer*—Michael S. Kachorsky, Manville
*FSWA Director*—P. N. Daniels, Trenton
*Executive Committee*—Frank Van Orden, Bernardsville and Anthony Maeri, Hammonton.

After the close of the business session Admiral J. K. Hoskins, Assistant Surgeon General of the USPHS and President of the Federation, presented Dr. Willem Rudolfs with a certificate of Honorary Membership in the Federation. In making this award Admiral Hoskins cited the outstanding work of Dr. Rudolfs as Chief of the Department of Water and Sewage Research at the New Jersey Agricultural Experiment Station at Rutgers University and for his work in the Federation as Chairman of the Research Committee.

MICHAEL S. KACHORSKY,
*Secretary-Treasurer*

## NEW MEMBER ASSOCIATION PROPOSED AT INTER-AMERICAN SANITARY ENGINEERING CONFERENCE

A long and important forward step in the solution of environmental health problems of the Western Hemisphere was taken during the week of June 10 in Rio de Janeiro, Brazil. In the new modernistic palace of Education and Health, over 200 sanitary and public works engineers, engineering educators, health officers, manufacturers and other interested persons met in the first Inter-American Regional Conference of Sanitary Engineering, to discuss sanitation problems of the Americas and to make the first move in establishing a permanent sanitary engineering organization in this hemisphere. The Institute of Inter-American Affairs and the Pan-American Sanitary Bureau, in collaboration with the National Health Department of Brazil, were sponsors of the conference while the Water and Sewage Works Manufacturers Assn. supported the meeting with financial aid, technical speakers and exhibits.

Representatives from Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, United States and Uruguay participated. A second regional conference including the nations of northern South America and Central America will be held in Caracas in September. Early next year the first conference covering all the 21 nations is expected to be held.

Dr. Ernesto de Souza Campos, Brazilian Minister of Education and Health, opened the meeting on the keynote of the establishment of closer ties of co-operation between sanitary engineers of the Americas thus founding a firm base for the improvement of environmental sanitation and health and the subsequent raising of living standards.

On the same premise Dr. Abel Wolman, with a paper on Sanitary Engineering as a Profession, led off the technical program which extended from Monday afternoon through Thursday. These sessions included presentation of papers on the following subjects:

sanitary engineering activities and water supply financing in each of the various countries represented; chlorination by A. E. Griffin and Gordon M. Fair; water laboratory control practice by H. W. Streeter and Alvaro Cunha of Brazil; various aspects of water supply, including design and maintenance, by Walter Dashiel of the Pan American Sanitary Bureau (Guatemala), John L. Hummel of the I.I.A.A. (Brazil), Saturnino de Brito of Brazil, H. G. Baity of the U.S.A., Roland Queneau of the Pitometer Co., Altino Pimenta of Brazil and H. A. Whittaker of the U.S.A.; mosquito, insect and malaria control by Thomas Hart of the I.I.A.A. (Bolivia) and Edward Hopkins of the Pan American Sanitary Bureau (Perú); community sanitation by E. G. Wagner of the I.I.A.A. (Brazil), Julio Basoalto of Chile, Henry H. Retter of the Pan American Sanitary Bureau (Perú) and Anthony Kranaskas of the I.I.A.A. (Uruguay); and sewage treatment by Adolfo Acevedo of Chile, Jesus Netto of Brazil and Carl Westphal of the Dorr Co. All the papers will be published in one bound volume which will be distributed to everyone registered at the conference as well as others who are interested.

The organization, resolutions and sanitary engineering education committees gave their reports at the business meeting on Friday. The following reports of the organization and education committees were adopted in full:

*Organization Committee*

The committee designated to study the need and possibility of forming a permanent organization which would include all the engineers who are interested in Sanitary Engineering activities in the American hemisphere, recommend the formation of an Inter-American Association of Sanitary Engineering, having for its principal object the necessity of a common agreement solving problems relating to sanitation and the establishment of general standards for the uniform and continuous protection of the people of the hemisphere.

The committee agreed to adopt as an objective of the permanent Association the same points as were outlined in the regional conference at Rio de Janeiro, in June, 1946, which follow:

1. Development of sanitary engineering.
2. An interchange of ideas and scientific information concerning developments of sanitary engineering in the Americas.
3. Establishment of standards of sanitation for the Americas.
4. Promote more rapid advancement in the sanitation of the several countries of America as a necessary basis for economic development.
5. Establish good will and better understanding between the engineers of the Americas.

The committee also agreed to propose for the consideration of the engineers present at the conference the following points:

1. Formation of an Inter-American Association of Sanitary Engineering with a Board of Directors composed of one representative from each country. Each country would also elect an alternate who would replace the Board Member in case the regularly elected Board Member would not be able to attend the Conference.

2. The Board of Directors would be presided over by a President elected by its members. The term of the President shall be one year. The members of the Board of Directors will serve for three years. At the first meeting, one-third of the members of the Board would be elected to serve for one year, one-third to serve two years and one-third to serve three years. Subsequently each director would be elected to serve three years.

3. At least one annual conference shall be held.

4. The Board of Directors shall be assisted by a permanent General Secretary and a Secretary. The latter shall be elected by the members from the country in which the next conference is to be held and his term shall be one year.

5. The Permanent General Secretary shall be proposed by the Director of the Pan-American Sanitary Bureau and must be approved by the majority of the directors of the Association. The majority of Directors of the Association may request the Director of the Pan-American Sanitary Bureau that a new secretary be proposed for their approval and he shall be required to comply with this request within 3 months.

The Pan-American Sanitary Bureau is especially designated as it is an existing official organization of all the American Republics.

6. The Association shall publish annually

the technical papers and discussions presented at the conferences.

7. A committee of three engineers shall be designated to present these plans at the conference to be held in Caracas, Venezuela, which will take place in September, 1946, and the committee shall have authority to discuss these resolutions with the engineers who will attend the conference and make any changes or include any suggestions which may be indicated within the spirit of the thought herein expressed.

8. The official language of the conference shall be Spanish, but the technical papers may in addition be published in Portuguese and English when desired.

*Sanitary Engineering Education Committee*

The Inter-American Regional Conference of Sanitary Engineering, meeting in Rio de Janeiro, Brazil, convinced that only with continental unity is it possible to promote the general welfare of the people of this hemisphere, and confident that the mutual aid of a policy of good neighborliness is the best instrument to guarantee the unity of the American nations, having in view the imperative necessity of raising the general standard of sanitary conditions in the Americas, principally that which can be attained by the action of sanitary engineers properly trained and appropriately employed in various public health services, international, national, state and local, recommends:

1. The inclusion in all civil engineering curricula in engineering schools of the American nations, of required courses in sanitary engineering covering water supply and sewage disposal and embracing about 120 classes, 60 of which would be laboratory.

2. The inclusion in all civil engineering curricula of two optional courses in sanitary engineering, one covering water purification and sewage treatment and the other, general sanitation subjects such as food sanitation, malaria and rodent control, garbage disposal, etc.

3. The creation of a School of Public Health in each nation, with additional schools on the basis of one to each 20 million population, in which will be given special courses of public health and sanitary engineering. In the conduct of these curricula it is desirable that the curricula or program be offered jointly by schools of public health, or departments of hygiene of medical schools, and the sanitary engineering departments of engineering schools in the same locality.

The special courses in sanitary engineering mentioned in the preceding paragraph should include the basic sciences such as chemistry, biology, engineering and public health, upon which the profession of sanitary engineering is based. The graduates of these courses must be able to identify, evaluate and describe in terms of their sanitary importance the environmental factors that promote and protect the public health as well as those that endanger it.

4. That there be required of applicants for governmental positions concerned with public health a certificate of graduation from a special course in hygiene and public health.

5. That research relative to sanitary engineering and public health be carried out in all public health and sanitary engineering schools.

6. That there be an active interchange of students and professors of sanitary engineering between the nations of this hemisphere.

*Resolutions Committee*

The resolutions committee presented 25 resolutions, 19 of which were approved. These concerned themselves mainly with the problems of planning and financing sanitary works, the establishment of standards and the dissemination of technical and general information on sanitation both to technical people and the public. Perhaps the most significant resolutions were those recommending that the importance of environmental health be brought to the attention of the United Nations in setting up the machinery for the maintenance of world peace and that the United Nations give favorable consideration to the continuance of international regional health program and agreements.

*Brazilian Committee for a Water and Sewage Works Association*

A fourth committee exclusively for Brazil presented a petition to form a Water and Sewage Works Association of Brazil which would be attached to the Federation of Sewage Works Associations and the American Water Works Association of the United States.

The Committee appointed Edmund G. Wagner temporary secretary to open correspondence with the American organizations to ascertain the possibilities of this Brazilian group becoming a part of the U. S. organizations.

For the future of Sanitation in Brazil this is a highly important and significant result of the Conference.

Plinio Penteado Whitaker, Director of the Water and Sewage Department of the City of São Paulo, acted as chairman of the conference and each technical session was presided over by a different chairman from each of the various countries represented.

Clarence I. Sterling, Jr. (U.S.A.) and Edmund G. Wagner (Brazil), both of the Institute of Inter-American Affairs, were co-chairmen of the program committee which included: Donald Snow, Pan-American Sanitary Bureau; Mario Belisario de Carvalho, Luiz Romeiro, Zeferino d'Avila Silveira of the National Health Department, Brazil; Antonio Barreto Goncalves Ferreira, Serviço Especial de Saúde Pública, Brazil; Lawrence M. Fisher, U. S. Public Health Service; John D. Faulkner, Institute of Inter-American Affairs, Brazil.

All those present were highly encouraged by the large attendance and the enthusiastic reception given the idea of an Inter-American organization such as the one proposed. From this excellent beginning there is every indication that within another year a permanent sanitary engineering organization embracing the 21 American Republics will be established.

EDMUND G. WAGNER,
*Acting Secretary*

Water and Sewage Works Association of Brazil

## NEW YORK STATE SEWAGE WORKS ASSOCIATION

1946 Spring Meeting
Utica, N. Y., May 24–25, 1946

The spring meeting of the New York State Sewage Works Association was held on May 24–25, 1946, at the Hotel Hamilton, Utica, New York. Seventy-five members and guests were registered. This was considerably below the expected number but it was felt that the railroad strike which was called at the time was responsible for the small attendance.

At a business meeting on Friday morning a committee was appointed by President Mann to consider the establishment of an "Arthur S. Bedell Memorial Award." This committee, consisting of Morris Cohn, F. W. Gilcreas and Edward J. Smith, was instructed to report to the Executive Committee at the earliest possible date.

The first paper in the technical session was given by Elvey A. Marshall, sewage treatment plant operator, Geneva, New York, entitled "Effect of Beet Cannery Wastes on the Operation of a Municipal Sewage Treatment Plant." Mr. Marshall explained the effects of beet wastes on the Geneva plant and the trouble caused by excess amounts of grit and the high chlorine demand of the beet wastes which make effective chlorination difficult. William A. Ryan of Rochester prepared a discussion of this report which was read by Glen Searls in Mr. Ryan's absence.

The second paper of the morning was one of unusual interest given by Roland W. Simpson, Sanitary Engineer of Gilbert Associates, Inc., of Reading, Pennsylvania, entitled "Ingenuity Tool of the Operator." Slides accompanied the paper illustrating several gadgets or innovations designed and built by operators to aid plant operation.

The annual Rating Awards were presented by A. W. Eustance, Chairman of the Rating Committee, to William Edwards, Senior Plant Operator of the Gowanda State Hospital Plant at Helmuth, N. Y., winner of the Annual Rating Contest, and to Edward J. Smith of Niagara Falls, winner of the previous Rating Contest.

At the luncheon, following an address of welcome by Hon. Boyd E Golder, Mayor of Utica, Bertram D. Tallamy, Deputy Superintendent of the Department of Public Works, State of New York, Albany, N. Y., gave an informative talk on "The Postwar

Public Works Program" and discussed the new proposed through road to be constructed by the Department of Public Works from the Jersey state line to Albany, thence across to Buffalo and ending at the Pennsylvania state line. Mr. Tallamy gave some interesting details of this proposed highway, which is scheduled for completion within five years.

The first paper of the afternoon session was given by F. W. Gilcreas, Assistant Director of the Division of Laboratories and Research, Albany, entitled "Inhibition of Sludge Digestion by Penicillin Manufacturing Wastes." Mr. Gilcreas referred to the trouble experienced at the Ley Creek sewage treatment plant operated by President Mann, when excessive quantities of penicillin wastes were discharged into the system.

"Transmission of Disease by Sewage," by Robert N. Clark, District Engineer, New York State Department of Health in Ithaca, was read by E. C. LaValley in Mr. Clark's absence. The history of the serious typhoid epidemic which occurred in Ithaca early in the century was discussed. The cause of intestinal illness and their methods of transmittal in sewage was explained.

In his paper on "Small Plant Operation," Herbert O. Johnson, Superintendent of the Belgrave Sewer District, Long Island, New York, explained some of the troubles of the small plant operator and pointed out the remedies.

The last paper of the afternoon was an interesting discussion entitled "Chlorine," by Wilmer H. Koch, Chemist, Niagara Operations, Mathieson Alkali Works, Inc., Niagara Falls. Mr. Koch presented some facts on the manufacture and handling of chlorine and the various precautions necessary.

At the evening banquet, Morris Cohn of Schenectady gave the "Eulogy of Arthur S. Bedell." High and just tribute was paid to Mr. Bedell, the former Secretary-Treasurer of the NYSSWA, who had guided the Association since its inception in 1929.

H. V. Crawford, Engineer, General Electric Company of Schenectady, showed a sound movie entitled "Clean Waters," which was prepared by the General Electric Company with the cooperation of various other agencies and health departments. The film dealt with the establishment of sewage treatment to abate pollution of rivers and other waters.

On Saturday morning the members attended a Sunrise Breakfast which featured a round table, ably directed by George E. Symons, Associate Editor of *Water and Sewage Works*, New York City.

A. F. Dappert,
*Secretary-Treasurer*

## OHIO CONFERENCE ON SEWAGE TREATMENT

Twentieth Annual Convention
Akron, Ohio, June 20–21, 1946

The Twentieth Annual Convention of the Ohio Conference on Sewage Treatment was held in the Mayflower Hotel at Akron on June 20–21, 1946, with 111 members and guests attending. D. D. Heffelfinger, Engineer-Superintendent, Division of Water and Sewage Treatment, Alliance, Ohio, Chairman of the Conference, presided at the various sessions.

An exceptionally interesting technical program was a feature of the meeting. Papers presented on June 20 were:

"Reports of Operation of Sewage Treatment Plants in Ohio," by G. A. Hall, Assistant Engineer of the Ohio Department of Health.

"The Sewer System Can Serve a Dual Purpose," by Morris M. Cohn,

Editor of *Sewage Works Engineering* and Sanitary Engineer of the City of Schenectady, New York, considered possible effects of household garbage grinders on sewer systems and sewage treatment plants.

"Oils and Greases—Their Effects on Sewage Treatment," by F. L. Rollins and George S. Long of the Akron sewage treatment plant.

"Important Considerations in Sludge Digestion" was a correlated discussion by Harry E. Schlenz, Vice-President and Sales Manager of the Pacific Flush Tank Company and Dr. A. M. Buswell, Chief of the State of Illinois Water Survey.

At the annual banquet Dr. William L. Davidson, Jr., of the B. F. Goodrich Company addressed the Conference on the subject of "Atomic Energy."

The Federation of Sewage Works Associations was represented at the Akron meeting by its Vice-President, Francis S. Friel of Philadelphia, who spoke on "Federation Activities."

The technical session on June 21 included the following papers:

"Construction and Operation of Military Sewage Treatment Plants in Australia," by Paul Beck, Chemist at the Rocky River, Ohio, sewage treatment plant.

"Stream Water Quality Standards," by F. E. DeMartini, USPHS Sanitary Engineer.

"Status of Operator's Certification," by F. Dean Stewart, Assistant Chief Engineer of the Ohio Department of Health.

"Industrial Waste—What Is It?" by George E. Symons, Associate Editor of *Water and Sewage Works* in New York, included methods of converting some wastes into valuable by-products.

"Concentration of Activated Sludge," by Don E. Bloodgood, Associate Professor of Sanitary Engineering at Purdue University at West Lafayette, Indiana.

A 30-min. sound film entitled "Concrete Facts" was shown by the Master Builders Company of Cleveland.

The General Electric Company presented a sound and color moving picture, "Clean Waters," explaining in interesting fashion the existence and consequences of stream pollution problems.

The following officers were elected for the ensuing year:

*Chairman:* L. C. Huffman, Dayton.
*Secretary-Treasurer:* G. A. Hall, Columbus.
*Executive Committee Chairman:* D. D. Heffelfinger, Alliance.

G. A. Hall,
*Secretary-Treasurer*

## PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

### 1946 Annual Meeting
### Gearhart, Oregon, May 22, 1946

The 1946 Annual Meeting of the Pacific Northwest Sewage Works Association was held at the Hotel Gearhart, Gearhart, Oregon, on May 22, 1946. Total registration was 100.

The meeting was called to order by President C. V. Signor, who introduced to the organization members who had returned from the armed forces and the new members.

The technical program commenced with discussions on the "Status of Water Pollution Control in the Pacific Northwest," with M. S. Campbell presiding, assisted by H. C. Clare, Division of Public Health Engineering, State Department of Health at Boise, Idaho; Curtiss M. Everts, Jr., Director of the Division of Sanitary Engineering, State Board of Health at Portland,

Oregon; Jack Taylor, Director of State Pollution Control Commission at Olympia, Washington and Roy M. Harris, Chief of the Division of Public Health Engineering, State Department of Health at Seattle, Washington.

The morning program continued with the following papers:

"Industrial Waste Treatment and Disposal Problems," was discussed by Fred G. Nelson of the Dorr Company in Los Angeles. This paper dealt mainly with the problem of treating cannery wastes, which is one of the more pressing problems of sewage works operators on the Pacific Coast. Pretreatment of these wastes was very thoroughly covered, from various methods of screening, vacuum flotation and sedimentation to the disposal of the sludge.

"Pulp and Paper Mill Waste Treatment by High Rate Filters," was the topic of a paper by R. G. Tyler, Professor of Sanitary Engineering at the University of Washington at Seattle. Professor Tyler covered the research work being done by his institution for the paper industry on the utilization and disposal of sulfite liquors and other wastes from paper mills.

"Reducing Hazards in Sewer Systems and Sewage Treatment Plants," was discussed by W. H. Wisely, Executive Secretary of the Federation of Sewage Works Associations, Champaign, Illinois. Supplementing the Federation's safety manual, Mr. Wisely emphasized the common minor hazards and referred to illustrative examples from his own experience as a sewage works superintendent.

At the noon luncheon Mr. Wisely spoke on "Aims and Progress of the Federation," citing the many accomplishments of recent years and the comprehensive program of service now being carried on.

The afternoon technical session, conducted by Wm. P. Hughes, commenced with "The Portland Sewage Collection and Treatment Project," by Ben S. Morrow, City Engineer at Portland. Mr. Morrow described, with explanatory maps, the various problems which had been overcome in developing the twelve miles of sewage collection and the treatment project at Portland. Discussions by R. E. Koon and John W. Cunningham followed.

A panel discussion covering the maintenance of sewage works equipment and the sale and disposal of digested sludge was led by E. A. Heiss, Earl M. Kelly, R. F. McLean, C. M. Howard, D. W. McNamara and Kenneth H. Spies.

At the annual dinner meeting, Dr. Paul R. Needham, Director of Fisheries of the State Game Commission, Portland, gave an interesting talk accompanied by colored pictures on the subject "The Effect of Organic Wastes on Fish Life."

The Kenneth Allen Award was presented to Wm. P. Hughes by W. H. Wisely. This award is made once in every three years, this award being the second to be presented to a member of the PNSWA for outstanding service in the sewage treatment field, as related particularly to the problems and activities of the Association.

At the business meeting the following officers were elected to serve during the ensuing year:

*President:* C. M. Howard, Seattle, Wash.
*First Vice-President:* H. C. Clare, Boise, Idaho.
*Second Vice-President:* K. H. Spies, Portland, Ore.
*Secretary-Treasurer:* Wm. P. Hughes, Lewiston, Idaho.
*FSWA Director:* M. S. Campbell, Seattle, Wash.

A special investigation committee, with Ray E. Koon as chairman, reported that it could not support the recently introduced method of treating sewage by ozone; that many cities have

been approached with a proposal to treat sewage by ozone and thus produce and effluent which would not pollute the water into which it is discharged. The special committee reported, however, that no important data to support statements of efficiency, either with respect to acceptable treatment and disposal of sewage or in the matter of cost of operation, were found. The committee recommended that until there is proof that the system is successful the Association advise officials against making any contracts for a system of sewage treatment which is not accepted by state health officers as being of a type which experience has shown to be reasonable in cost and successful in operation. This report was unanimously approved by the assembly and the Secretary instructed to send a copy of the report to all cities of the northwest where consideration may be given to the treatment of sewage to prevent stream pollution.

Roy M. Harris, Chairman of the Hatfield Award Committee, reported that no operating reports had been received which would meet the basic requirements for consideration of this award, and recommend the following:

1. That interest in this award be stimulated during the present year so that suitable reports may be prepared for judging in 1947.

2. That a suitable certificate be awarded by the Pacific Northwest Section for the most outstanding annual report prepared by a member of this section, provided, however, that no report be considered for judging unless it meets the standards prescribed by the Federation of Sewage Works Associations, as published in SEWAGE WORKS JOURNAL (January, 1946).

3. That the Wm. D. Hatfield Award Committee be authorized to design and have printed a suitable certificate as outlined in previous recommendation (2).

The recommendations were approved.

WM. P. HUGHES,
*Secretary-Treasurer*

## MEMBER ASSOCIATION MEETINGS

| | | |
|---|---|---|
| North Carolina Sewage Works Association | Carolina Hotel, Raleigh, N. C. | Nov. 18-20 |
| **Federation of Sewage Works Associations** | **San Francisco, Calif.** | **July, 1947** |
| Ohio Sewage Works Conference Group | Deshler Wallick Hotel, Columbus, Ohio | Oct. 2-3, 1947 |

# Federation Affairs

## I KNEW ARTHUR BEDELL

By Morris M. Cohn

I have had many difficult assignments in my time—but none has ever been more fraught with pitfalls than delivering a eulogy of a man I knew well. That is the trouble—I knew Arthur Bedell so well that I really didn't know him.

We seldom see the things that are part of us. They are so much a portion of ourselves that we are troubled with personal astigmatism. That was the way Arthur Bedell was. He was part of our scene, a part that was so natural to us that we never thought to think about him. We assumed that he would always be there, doing the things he had always done and playing the role he had always played.

And then one day, he was gone and there was a gap in the contemporary sanitary engineering scene that no one but Arthur Bedell could fill. Now I have the task of saying something significant about someone who little needs any significant comments.

Seneca said, "Reputation demands words —but renown can be content with man's judgments." There is little need for me or anyone to add words to Arthur Bedell's renown—our judgments suffice to set him on a pedestal.

I am seldom at loss for words but I grope clumsily to add further proof of the worth of the man whom we honor tonight. Yet, something should be done to pay honor to the man who made this Association possible, at the first meeting he missed since the New York State Sewage Works Association was created years ago. Somehow, we seem like a watch without a mainspring today—and truly we are just that, because we have lost our driving force. I doubt if our meetings will ever be the same without Arthur Bedell around to make order out of chaos.

Arthur Bedell was ideally fitted by professional preparation and experience to play his role in the sewage field. He obtained and gave truly international training and service. He received his B.A. degree from Dartmouth; his B.S. in C.E. from Robert College, Istanbul, Turkey; and his special training in public health from M.I.T. and Johns Hopkins. He taught and held administrative positions at his Turkey Alma Mater and served as a sanitary expert for the American Red Cross Commission in Greece after the first World War. He served briefly with the Rockefeller Foundation, to add another stone in his structure of international service. Why, he was even born in Brooklyn—and there has been some belief that Brooklyn does not belong to the United States.

Few of those who were associated with him knew of his broad professional background. He was the Chief Engineer of the Utah State Health Department before taking up service with the N. Y. State Health Department where he had recently turned 21 years of service.

It is the simple truth that he *was* the New York State Sewage Works Association. He served as its Secretary-Treasurer from the date of its organization in 1929 to the time of his death at which moment, he was working and planning for this spring meeting, and arranging for the recent sewage works school.

He never aspired to the presidency of the State Association and presidents came and presidents went, and the Association held to its even course because Arthur Bedell was behind the scene guiding the hands of the officers. Your speaker, as one of the past presidents, can attest to the way his steady hand came into play whenever the Association affairs wavered even momentarily.

He could not hide his light under a bushel and in 1940, he was called to the Vice-Presidency of the Federation of Sewage Works Associations and served as its President in 1941 and 1942. He did much in reorganizing the Federation from a

"paper" organization into its present, capable, serviceable form. Those few of us who served as his "kitchen cabinet" when he was guiding the destinies of the Federation learned to respect him for his calm judgment and to love him for his simplicity of approach.

These are the facts about Arthur Bedell —Engineer, unselfish worker in his professional sphere. But what of Arthur Bedell the man? What can we learn of his character which we took as a matter-of-fact when he was with us? I would like to stress a few of his characteristics and plead that we emulate them for the good of the profession which he served until death.

He walked in dignity. He seemed ever conscious of a respect for his calling, for himself as a member of his profession, and for his co-professionals. I seldom heard him speak above a low conversational tone; never heard a blasphemous word from his lips; never heard a derogatory remark voiced. He abhorred blatency and any action which would label the profession as cheap or uncultured. Above all, he looked and acted the man of dignity.

He walked in humility. He was ever willing to learn, to see the right of others' arguments and to recognize their points of view. He had no exalted opinion of himself which is always the stamp of those who have the right to have an exalted opinion of themselves. He viewed himself merely as a link in the long chain of public health—and he was a strong link.

He was scientifically honest. He never compromised with the truth even though a compromise would have meant less work and shorter hours of labor. In fact, he had brought work home with him for his last weekend. He maintained rigid standards of perfection and technical practice. He left his impression on sewage treatment design in New York State by turning thumbs down on inadequate design, half truths, half-assumptions. He searched for truth in basic engineering design and decisions.

He was helpful to others. Few knew how helpful he was to his fellow engineers. He gave unstintingly of his time and his ebbing energies to those who needed the ability which he hid behind his humble mien. His helpful spirit built the Association and made of every member a friend.

There are many lessons to be learned from the life of Arthur Bedell, in an age of superficialities and ostentation—lessons which will improve this profession and gain the public respect for which we seek.

We must learn to walk in dignity. We should learn the "bedside manner" achieved by the medical profession for there is as much reason for a reassuring mien, a gracious approach and a kindly tonal inflection in the field of preventive hygiene as there is at the bedside of the ill. The major ingredient of this so-called bedside manner is pride in, and respect for, the profession which the engineer represents, and the major ingredient of professional pride is the full knowledge and appreciation of the history of the calling and of the men who made that history, and are continuing to write the public service which the profession performs. If we remember the "greats," including Arthur Bedell, who came before us and attempt to walk as they walked, we will attain dignity and public esteem for the sewage works field.

We must learn to walk in humility. We must be anxious to learn because we are merely on the threshold of knowledge of the intricate forces which can be utilized for the treatment, utilization and disposal of the wastes of life and living. We must recognize our own deficiencies and strive to correct them, and we must apply this to our treatment plants, in design, construction, equipping and operation. We must learn to strengthen our deficiencies rather than to cover them up. If I may put it another way, we must learn to "rate" our plants in our *minds* as well as on a *rating schedule*.

We must be scientifically honest. The true measure of a man's inherent honesty is laboratory control. Laboratory results and operation records must reflect what the plant *does* rather than what we *hope* it is doing.

We must be helpful to others. This is a new profession. It has gained maturity only because there has been a free interflow of ideas and knowledge from those who know to those who must learn. Every one of us has the responsibility to offer information which we have to others. The short school, the technical press, the technical meeting and the man-to-man visit at a treatment plant are all opportunities for helpfulness which we must not overlook.

Every passing of a pioneer in sewage treatment places added responsibilities on those who pick up the torch and carry on. If we translate into practical service the things for which Arthur Bedell stood and worked, we truly honor the man who breathed his character and spirit into this Association, the Federation of Sewage Works Associations, and everything for which all sewage works associations stand.

I would like to propose that a new Award be established—the Arthur S. Bedell Award—to be presented yearly to that person who has done the most in New York State to dignify sewage treatment and stream sanitation and to gain acceptance of its public health functions. By so doing, we would stimulate others to live as he lived and to raise the status of the work for which he strove.

"If you will observe, it doesn't take
A man of great mold to make
A giant shadow on the wall;
And he who in our daily sight
Seems but a figure slight and small,
Outlined in fame's illusive light
May stalk, a silhouette sublime
Across the canvas of his time."

If I have succeeded in outlining the silhouette of Arthur Bedell, across the canvas of his time, I have fulfilled my mission.

## 19TH ANNUAL MEETING A GREAT SUCCESS

A record breaker in every respect, the Nineteenth Annual Meeting of the Federation, held at Toronto, Can., on October 7-9, 1946, reflects great credit to the host Canadian Institute on Sewage and Sanitation. Registration was 812—exactly 200 more than the previous record of 612 established at Chicago in 1943—and included an all-time high of 200 ladies.

Dr. A. E. Berry, Secretary of the Canadian Institute, headed the Local Arrangements Committee which functioned so efficiently and successfully in the planning and conduct of the conference. Each technical session and entertainment event proceeded with a smoothness and precision which bespoke the infinite attention given every detail by the hosts. Just a few weeks before the meeting it appeared that the situation in regard to hotel accommodations for the meeting was all but hopeless; by unstinting work and resourcefulness, the local committee surmounted this obstacle so well that all visitors were housed with unusual dispatch and convenience.

Early comers who were present for pre-registration on Sunday evening, October 6, were privileged to enjoy a pleasing choral concert by the Leslie-Bell Singers of Toronto. About 250 were in attendance at this function.

The meeting was convened at 9:00 A.M. on Monday, October 7, by President J. K. Hoskins, who spoke briefly on the progress made by the Federation during 1946. The short business session was concluded by the presentation of the report of the Executive Secretary-Editor by W. H. Wisely. Details of current operations of the Federation and plans for the near future were described.

### Technical Program

The excellent technical program arranged for the meeting by the Publications Committee was undoubtedly largely responsible for the unprecedented registration. The informative discussions from the floor following each paper were proof that the topics were timely and well presented. A summary of the program follows:

Sewage Treatment at Toronto. By WILLIAM STORRIE.
Discussion by ALMON L. FALES.

Characteristics and Methods for Treatment of De-inking Wastes. By W. W. HODGE and P. F. MORGAN.
Discussion by WILLIAM S. WISE.

Industrial Alcohol Production by the Ontario Paper Company, Ltd., from Sulfite Waste Liquor. By H. G. JOSEPH.

Discussion by R. G. TYLER.

Standards of Stream Sanitation. By H. W. STREETER.
Discussion by MILTON P. ADAMS.

The Hypochlorite Process for Treatment of Wool Scouring Wastes. By HARRY A. FABER.

Discussion by JOSEPH L. CAMPANELLA.

Scum Control in Digesters. By R. S. RANKIN.
Discussion by HARRY E. SCHLENZ.

Incineration Problems. By GEORGE J. SCHROEPFER.
Discussion by MARK B. OWEN.

Evaluation of Methods of Heating Sludge Digestion Tanks. By HENRY J. MILES.

Discussion by WILLEM RUDOLFS.

Present Status of Sludge Gas Utilization. By RICHARD H. GOULD.
Discussion by A. M. BOEHM.

Financing Sewage Systems. By FRANCIS S. FRIEL.
Discussion by F. M. VEATCH.

British Developments in Sewage Purification Practice. By JOHN HURLEY.
Discussion by F. W. MOHLMAN.

The Army Sewage Treatment Program. By HAROLD A. THOMAS, JR.
Discussion by ROLF ELIASSEN.

As usual, the Operators' Forum on the last day of the meeting was one of the features of the technical program. Led by H. S. Nicklin, President of the Canadian Institute, participation in the discussions was general and spontaneous. The discussion topics touched upon almost every phase of sewage works operation, and the three hours allotted to the session were all too short.

### Entertainment Events

The attendance of 450 at the Federation Luncheon on Monday, October 6, set a new mark for this event. President Hoskins presided. Following the luncheon, Frank Woodbury Jones, registrar of the Quarter Century Operator's Club, presented the members of the club, who had been seated at the special table. The greetings of the city of Toronto were extended by H. E. Mac Callum, City Controller, who appeared in the stead of Mayor Saunders. The feature speaker was Dr. J. T. Phair, Deputy Minister of Health of Ontario, whose topic was "Environmental Sanitation in the Field of Public Health." As a veteran public health administrator, Dr. Phair spoke authoritatively on the objectives of environmental sanitation, and urged sanitary engineers to give greater emphasis to the public relations aspects of their activities. The luncheon program was concluded by a showing of the moving picture "Clean Waters," by courtesy of the General Electric Company.

The Canadian Institute Dinner on Monday evening drew a capacity attendance, with nearly 650 persons being present. Institute President H.

S. Nicklin presided. Hon. Russell T. Kelley, Provincial Minister of Health of Ontario, gave a short but scintillating address that was liberally flavored with humor. He emphasized the value of meetings such as this in strengthening the bond between the United States and Canada. The program was concluded with a variety of excellent entertainment which made the event a complete success.

The Annual Dinner-Dance on Tuesday evening also attracted a capacity crowd of almost 650 persons. With President Hoskins presiding, the dinner program was devoted entirely to the announcement and presentation of Federation awards for 1945 and 1946. Past President A. E. Berry, Past President C. A. Emerson and Dr. W. D. Hatfield assisted President Hoskins in presenting the awards, and the ceremony was both interesting and impressive. Entertainment during the remainder of the evening was more than adequately provided by the dance and Club Room.

The Club Room, an innovation at Federation meetings, was an outstanding success as conducted by the Canadian Sanitation Equipment Association and the WSWMA. These sessions were well attended and added measurably to the good will and fellowship that prevailed during the conference.

## Ladies' Entertainment

Nearly 200 ladies were present to enjoy the unusually appealing ladies' entertainment program that had been planned by the committee headed by Mrs. J. B. Kinney. The Sunday evening choral concert, enthusiastically received by all, initiated the program. On Monday, the term "entertained royally" was made a fact when the ladies were taken for a tour of the Ontario Provincial Parliament Buildings, followed by a reception and tea as guests of Lieutenant Governor Albert Mathews and Mrs. Mathews. This was a feature occasion.

On Tuesday, the ladies were given a luncheon at "The Old Mill," one of Toronto's centers of interest. A delightful bridge party in the afternoon completed the special series of events arranged for the ladies.

## Convention Attendance Award

For the fifth time in succession, the Central States Sewage Works Association won the trophy symbolizing the Convention Attendance Award. A total of 71 CSSWA members aggregated more than 32,000 man-miles of travel in attending the meeting, to win over the 18,000 man-miles travelled by members of the Canadian Institute.

## Board of Control Sessions

The annual business sessions of the Board of Control were held on Sunday, October 6, and Wednesday, October 9. Complete minutes of these meetings will be published in the January, 1947 issue of THIS JOURNAL.

The 1946 honors and awards approved by the Board and presented at the Federation Dinner were as follows:

*Honorary Member*
William John Orchard

*Harrison Prescott Eddy Award*
H. Heukelekian

*George Bradley Gascoigne Award*
LeRoy Winfield Van Kleeck

*Charles Alvin Emerson Award*
F. Wellington Gilcreas

*Kenneth Allen Awards*
George Martin (CSSWA)
Frank E. DeMartini (FSRA)
Theodore R. Lovell (ISWA)
Thomas J. Doyle (MSWA)
John R. Downes (NJSWA)
Harold Benedict Gotaas (NCSWA)
William P. Hughes (PNSWA)
E. J. M. Berg (TSWS)
John Henry Garner (ISP)

*William D. Hatfield Award*
Walter M. Kunsch.

At the October 6 session of the Board the following officers were elected:

Francis S. Friel, *President*
George S. Russell, *Vice-President*
W. W. DeBerard, *Treasurer*
A. F. Dappert, *Director-at-Large*.

San Francisco was confirmed as the site of the Twentieth Annual Meeting in July, 1947 and invitations for future meeting places were received from Denver, Detroit, Toledo and Boston.

## Canadian Business Luncheon

On Tuesday, the Canadian Institute conducted its annual business meeting at the King Edward Hotel, with 165 members in attendance. Officers of the Federation were guests at this function and each of them spoke briefly. Officers elected by the Institute for the year 1946-47 were: *President* Nicol MacNicol; *Vice-President* G. H. Richards; *Trustees* F. G. Browne and L. G. McNeice.

## Manufacturers' Exhibit

Thirty-five manufacturers participated in the exhibit arranged by the Water and Sewage Works Manufacturers' Association and the Canadian Sanitation Equipment Association. Though somewhat smaller than expected, the exhibit was nevertheless interesting and informative.

## Convention Committees

Personnel of the various committees which functioned so well in making the Nineteenth Annual Meeting such an outstanding success are listed herewith:

### CONVENTION MANAGEMENT COMMITTEE
Albert E. Berry, *Chairman*

Stanley Shupe — W. J. Orchard
W. H. Wisely — A. T. Clark

### LOCAL ARRANGEMENTS COMMITTEE
Albert E. Berry, *Chairman*

G. A. H. Burn — H. S. Nicklin
J. A. Daly — T. M. Parr
A. R. Fraser — George Phelps
George Gass — G. G. Powell
N. J. Howard — W. B. Redfern
J. B. Kinney — J. P. Russell
Nicol MacNicol — R. H. Shook
George Morgan — William Storrie
C. H. Taylor

### PROGRAM COMMITTEE
(Federation Publications Committee)
F. Wellington Gilcreas, *Chairman*

Rolf Eliassen — C. C. Larson
Francis S. Friel — F. W. Mohlman
Carl C. Green — F. M. Veatch
W. H. Wisely

### PUBLICITY AND ATTENDANCE COMMITTEE
Linn H. Enslow, *Chairman*

R. J. Cleary — A. Prescott Folwell
Morris M. Cohn — W. S. Foster
J. A. Daly — J. P. Russell

### HOTEL ARRANGEMENTS COMMITTEE
Nicol MacNicol, *Chairman*

N. J. Howard — W. L. McFaul
R. F. Lamson — George Phelps
W. B. Redfern

### REGISTRATION COMMITTEE
G. A. H. Burn, *Chairman*

George Gass — T. M. Parr
T. M. S. Kingston — W. H. Richl
H. G. Tyler

### LOCAL HOST COMMITTEE
H. S. Nicklin, *Chairman*

J. A. Daly — A. R. Fraser
R. J. Desmarais — G. G. Powell
G. H. Ferguson — Stanley Shupe

### FINANCE COMMITTEE
J. B. Kinney, *Chairman*

W. C. Miller — G. H. Richards
R. H. Parsons — R. H. Shook
William Storrie

### ENTERTAINMENT COMMITTEE
George Morgan, *Chairman*

C. G. R. Armstrong — R. J. Desmarais
A. M. Billborough — David Jack
J. P. Russell

### CLUB ROOM COMMITTEE
C. H. Taylor, *Chairman*

George Gass — J. B. Kinney
N. J. Howard — George Morgan
T. M. Parr

### LADIES' ENTERTAINMENT COMMITTEE
Mrs. J. B. Kinney, *Chairman*

Mrs. Albert E. Berry — Mrs. Nicol MacNicol
Mrs. George Gass — Mrs. George Morgan
Mrs. N. J. Howard — Mrs. G. G. Powell
Mrs. William Storrie

### WATER AND SEWAGE WORKS MANUFACTURERS' ASSOCIATION, INC.

William C. Sherwood ..... President
Albert E. Paxton ..... Vice-President
Edgar J. Buttenheim ..... Treasurer
Arthur T. Clark ..... Secretary-Manager

### CANADIAN SANITATION EQUIPMENT ASSOCIATION

George Gass ..... Chairman
George Morgan ..... Secretary-Treasurer
Charles H. Ley ..... Auditor
J. B. Kinney ..... CISS Director

# Reviews and Abstracts

Edited by

H. GLADYS SWOPE *

Allegheny County Sanitary Authority,
4501 Center Avenue, Pittsburgh 13, Pa.

**Sedimentation and the Design of Settling Tanks.** By THOMAS R. CAMP. *Proc. Am. Soc. of Civil Eng.*, **71**, 455–486 (April, 1945).

This paper is beyond the scope of an abstract because of the mathematical treatment presented and because of the numerous graphs and drawings so necessary for illustrating the author's development of the paper. As stated in the synopsis the purpose of the paper is, "to collect the known principles of sedimentation essential to the development of design theory, and to present the theory of design developed to a stage which will permit its use in practice."

The paper is divided into ten topics, designated as follows: (1) Settling Velocities of Individual Particles, (2) Nature of Settling Processes in Water and Sewage Treatment, (3) Settling Analyses of Suspensions, (4) Clarification Theory for an Ideal Basin, (5) Tractive Force and Bed-Load Movement, (6) Effects of Turbulence on Sedimentation, (7) Flocculent Suspensions, (8) Overflow Rate, Detention Period, Velocity, and Tank Dimensions, (9) Short-Circuiting and Stability, and (10) Conclusions. Examples of the use of theory are presented.

DISCUSSIONS

*Proc. Am. Soc. Civil Eng.*, **71**, 1148–50, 1379–86 (April, 1945); **72**, 249–250, 413–18.

By Norval E. Anderson, **71**, pp. 1148–49. Mr. Camp's mathematical presentation should prove useful in settling tank studies. It appears, however, that the conclusions for primary settling and particularly final settling tanks for the activated sludge process may be questioned on the basis of operating data results of plant-size experiments.

It is stated that density currents would be less with shallow tanks. Numerous tests on the 126 ft. diameter tanks at the Southwest Works of the Sanitary District of Chicago indicated that the density current velocities were approximately in inverse ratio to the flow depth. In these tests the effects of different depths of tank were obtained by using various depths of sludge blanket. Tests in rectangular settling tanks at Columbus, Ohio, and at Wards Island, New York, showed relatively higher velocities of density currents. In these tanks the ratio of length to depth is relatively large.

The location of the sludge drawoff at the effluent end of the tank may be questioned. Mr. Camp states that drawing sludge from the inlet end results in a mixture of fresh sludge short-circuited from the density current and stale sludge scraped from the effluent end, and that short-circuiting may be avoided if the drawoff is located at the effluent end. This short-circuiting should not be avoided since the drawing of fresh sludge for return to the aeration tanks is to be desired. If the drawoff is located at the effluent end the length of time the denser sludge remains in the tank is governed for the most part by the speed of the scrapers. This results in greater average age of the sludge than would be obtained in tanks with the drawoff at the inlet end.

Elimination of connecting conduits between aeration tanks and final settling tanks, suggested for the purpose of avoid-

* It will be appreciated if Miss Swope is furnished all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

ing high inlet velocities and destruction floc, has not been found desirable in studies made by the Sanitary District of Chicago. In large plants an uneconomical layout and a sacrifice of flexibility results. It might be practical in a small plant. Tests made at three activated sludge plants of the Sanitary District indicated practically no change in the settling characteristics of the aeration tank effluent after a fall over a weir and flow through a Venturi meter and a length of conduit and aerated channel.

By R. A. Mulholland, 71, pp. 1149–50. It appears that in some cases consulting engineers do not go thoroughly into the theory of sedimentation when designing settling tanks. This has been particularly true in the design of sewage treatment plants and has resulted in inadequate settling.

In recent years several plants have been built without connecting conduits between the aeration and settling tanks. Most of the Hay's process plants have been so arranged in current years.

By P. Charles Stein, 71, pp. 1379–83. Mr. Camp's paper develops the more important parts of the problem of sedimentation, and design principles are formulated. It should bring out the fact that depth divided by settling time, not depth or time alone, is the important factor in removal of suspended matter.

The paper exposes the neglect with which investigators have treated the mechanism of flocculation and its relationship to the settling problem. It may be shown that the number of contacts between particles per unit volume per unit of time is proportional to the volumetric concentration and is independent of the size of the particles. Thus, the effect of flocculation on sedimentation should be quite important where the volumetric concentration of suspended matter is high, as in sewage treatment processes. It appears that the shallow tanks indicated by the general settling theory are also more favorable for flocculation during settling.

By Lynn Perry, 71, pp. 1381–86. During the last generation thought and method of attack on principles of flow and fluids has changed radically. Design in the past has been based largely on empirical methods; it now remains for the development of fluid analysis based on rational fundamentals.

Radial flow sedimentation tanks have several faults, among them being the tendency toward unequal flow in different quadrants. Examination of results of tests on the Chicago Southwest tanks seems to indicate that deep tanks are unnecessary. It may be that some tanks have been built deeper than necessary, perhaps in an effort to save space. Or it may be that undue weight has been given to the theoretical period of detention.

The practice of drawing sludge from the effluent end of a tank is not desirable. Sludge should be drawn as far from the effluent weir as possible as this arrangement provides for resedimentation.

By E. Sherman Chase, 72, 249–50. The characteristics of solids to be removed by sedimentation in sewage treatment processes are so varied that no formula would have general application. Effluents from the same type of secondary treatment contain solids that will vary from plant to plant and time to time.

The importance of overflow rates rather than detention periods has been realized by designers for many years. Shallow sewage polluted streams demonstrate the effectiveness of low depths in clarification. The tray clarifier was developed some time past but its practicability has not been demonstrated.

The design of tanks will continue to be based on judgment and experience, along with necessary theoretical computations. Mathematical ability of a high order is necessary in using elusive theoretical formulas and not all designers are so fortunate to possess this facility.

By Rolf Eliassen, 72, pp. 413–18. Mr. Camp states that "the settling characteristics of the suspensions to be clarified are rarely considered in the design of settling tanks." These settling characteristics may be defined, on the basis of his experimental work, in terms of overflow rates of from 200 to 2,000 gal. per sq. ft. per day. A random selection of 13 sewage treatment plants throughout the United States show design overflow rates well within these limits. The figures range from 545 to 1,868 gal. per sq. ft. per day. This would

indicate that settling characteristics have been considered. It appears that the major difference between practice and Mr. Camp's conclusions is in detention times. Present design is based on periods of from one to four hours with tank depths varying from 5 to 15 feet. Mr. Camp "places particular emphasis on the need for tanks with short detention periods, shallow depths, and relatively high velocities of the liquids flowing through the tanks."

Tests have shown that greater short-circuiting is found in circular settling tanks than rectangular units, though the average effect on efficiency appears small. Choice between the two types appear to depend on the preference of the designer and economy of plant design.

The design of a tray settling tank is presented which would utilize shallow depths and high velocities. Such tanks have been available in the sewage treatment field but only a few installations have been made.

T. L. HERRICK

**Dewatering, Incineration, and Use of Sewage Sludge. A Symposium.** *Proc. Am. Soc. Civil Eng.*, 69, 71 (Jan. 1943).

DISCUSSIONS

By C. R. Velzy, 71, 77–78 (1945). The papers and discussions of this symposium indicate improvements and economies to be attained and point to possible improvements. At some plants it has been possible to sell sludge for use as a fertilizer. Improvements in sludge disposal processes have reduction in costs as the end in view.

Need for highly trained supervisory personnel and skilled operators is obvious. Such personnel is needed for efficient operation and for research and development.

In new designs selection of type of sludge disposal must be based on analysis and economical considerations. Disposal of sludge at sea at some cities is still the most economical method. Sand drying beds are most economical for small plants.

BY GEORGE J. SCHROEPFER. *Proc. Am. Soc. Civ. Eng.*, 71, 78–84 (1945).

Many of the problems of sludge disposal are presented in the papers of this Symposium and in the discussions. Mr. Genter presented valuable information on sludge disposal, but bases comparisons on a per capita basis. This does not appear sound as a comparison of costs and efficiencies on that basis penalizes a plant with a treatment process more effective than another or which by chance receives a stronger sewage.

On a per capita basis it may be shown that the sludge disposal costs at Minneapolis-St. Paul were 9.64 cents per year per capita, compared to 5.60 cents average for six plants employing elutriation. The order is reversed when the tonnage of solids removed is used as basis. On this basis the costs per dry ton of solids filtered are $2.23 and $2.60, respectively. On the basis of solids actually filtered the figures per dry ton are $2.23 and $7.78.

As regards the use of sludge as fertilizer it is to be remembered that raw sludge has objectionable characteristics, including a possible health hazard. The policy at the Minneapolis-St. Paul plant has been to allow farmers to haul sludge cake only during the early winter months from October to January. The use of fresh filter cake is not allowed on lawns and gardens in the cities. The District stores the filter cake for a period of two years, after which the material is in satisfactory condition for use. It has been the policy to furnish the material without charge and the use has increased from 21 tons in 1939 to 11,580 tons in 1943.

T. L. HERRICK

**Computing Coagulant Requirements in Sludge Conditioning.*** BY A. L. GENTER. *Proc. Am. Soc. Civil Eng.*, 71, 926–28, 1289–94, 1559–60 (May, 1945).

DISCUSSIONS

By Paul D. McNamee, pp. 926–928. Mr. Genter's formula for computing coagulant requirements should prove useful. The formula showed that the Washington, D. C., plant used more coagulant than is indicated by the equation. This has been confirmed by laboratory work. Use of excess coagulant at this plant has been occasioned at times by clogging of the

* NOTE: The original paper was abstracted in SEWAGE WORKS JOURNAL, 17, 188–191 (Jan., 1945).

NOTE: The abstract of the original article appeared in SEWAGE WORKS JOURNAL, 18: 589 (May, 1946).

elutriated sludge line. Sludge screening facilities and a different type of dosing equipment are needed to correct the condition.

Any fault with the equation would probably be found in the second part, which shows the ferric chloride requirements to be a function of the ratio of volatile matter to mineral matter in the sludge. The derivation was based on eight sewage sludges. Remarkable agreement is shown between coagulant requirements and the volatile-mineral matter ratio, though this is difficult to explain as the determination of the volatile matter complicates matters. The organic content of a given sludge is probably lower than the volatile content due to inorganic matter being changed by ignition into other forms, and the loss of sulfur dioxide and carbon dioxide from sulfates and carbonates.

The formula makes it possible to evaluate the effect of elutriation. By its use one can compute the savings of coagulant that may be realized.

By D. L. McLean, pp. 1289–1291. Mr. Genter has presented an ingenious method of determining the coagulant requirements of sludge. Operating results at the treatment works of the Greater Winnipeg Sanitary District indicate that the coagulant requirements as indicated by his formula are in close agreement with actual usage. Results for 1944 showed an actual rate of usage of 2.8 per cent ferric chloride. Use of the formula indicates 1.03 per cent ferric chloride for the alkalinity demand and 1.73 per cent for the solids demand, a total of 2.76.

On a special plant test in which digested sludge was filtered without elutriation, ferric chloride in excess of 9 per cent was required. The computed demand was 7.2 per cent for the liquid portion or alkalinity demand and 2.1 per cent for the solids demand, or a total of 9.3 per cent.

By K. Franschina, pp. 1291–1294. Mr. Genter's mathematical expression for determining coagulant requirements should prove useful. As pointed out, its use in plant practice presupposes reliable sampling and analytical methods, and careful filter operation.

Regarding the first part of the formula, wherein the quantity of ferric chloride required to react with the water portion of the sludge is determined, it may be shown, theoretically, that the pH value of the conditioned sludge should be about 4 at the completion of the reaction with the bicarbonates and before any coagulant is available for the solids demand. With elutriated digested sludge this does not appear to be the case. At the Richmond-Sunset plant successful filtration is obtained at a pH of about 6, indicating that some titratable alkalinity remains.

In the second part of the formula the "solids demand" is determined by an empirical coefficient and the ratio of volatile matter to ash. This ratio is important in studies of economies that may be realized by utilization of digestion and elutriation. The amount of coagulant is presumably determined by the organic matter content of the sludge solids. This probably is only approximated by the determination of volatile matter by ignition as some inorganic matter is converted to other forms. Furthermore, the absolute determination of the weight of dry solids is difficult due to loss of the more volatile fractions and the absorption of moisture during weighing.

Data for 1941 at the Richmond-Sunset plant are presented in Mr. Genter's paper. Weighted averages for subsequent periods, except for the fiscal year 1943–44, show close agreement between the actual dosage of ferric chloride and the computed dosage. Likewise in those years the value of the constant K in the second part of the formula approximated 1.6, the value set for careful filter operation. In 1943–44 the value of K was 2.04. This can be attributed to in part to new and inexperienced operators.

Figures by months for the 1944–45 fiscal year showed rather wide variations, though the yearly average dosage checks closely with the computed dosage. The value of K varied from a high of 2.18 in September to a low of 0.70 in December. Here again the high value was due in part to new operating personnel. The low values are more difficult to explain but are believed to be partly due to the abnormal condition of the single stage digestion system.

By Walter H. Brown, pp. 1559–60. At the Cranston, R. I., sewage treatment works Buechner funnel tests were first used to

check Mr. Genter's formula, and it was found that the calculated dosage closely checked the actual. However, when the indicated dosage was used in actual practice with clutriated sludge results were very poor. About 80 per cent more ferric chloride than indicated by the formula was necessary for good results. Examination of the chemical feed equipment disclosed that the apparatus was erratic. This equipment was discarded and a volumetric type feeder, designed at the plant, was installed. Dosages approaching the theoretical were obtained by use of this equipment. Further improvement was obtained by correcting short circuiting in the mixing tank.

T. L. HERRICK

**Concentration of Sewage Sludge. A Symposium.** *Proc. Am. Soc. Civil Eng.*, 71, 599–600 (April, 1945).

Discussion. By C. R. Velzy. Mr. Goudey indicates that raw sludge is concentrated with the same percentages of chemicals as are needed for digested sludge and concluded that for concentration digestion is unnecessary. However, aside from concentration, digestion reduces the quantity of solids to be handled, eliminates nuisance in sludge disposal, and produces a combustible gas that can be utilized.

There is not much to be gained in the concentration of digested and primary sludges. Digested sludge can be sufficiently concentrated in the digestion tank, and primary sludge densities can be controlled by the pumping schedule.

Concentration may result in considerable gain when working with waste activated sludge. Moderate results may reduce the volume to be handled to one-half or even one-third of the original volume. Results at Los Angeles and New York indicate that better concentration can be obtained by thickening aeration tank effluent than by thickening waste sludge.

*Note:* The original paper was published in *Proc. Am. Soc. Civil Eng.*, 70, 1275–1296 (Oct., 1944). An abstract of the original paper appears in the SEWAGE WORKS JOURNAL, 17, 188–191 (Jan., 1945).

T. L. HERRICK

**Gas Engine Power for Sewage Treatment Plants.** BY ALLEN J. BURDOIN. *Journal of the Boston Society of Civil Engineers*, 33, 29–52 (Jan., 1946).

The use of gas engines has become quite common in large and medium sized sewage treatment works. Due to the use of sludge gas as fuel the savings that can be realized are important. Since the heat from the cooling water and the exhaust can be readily recovered and utilized, the efficiency of the engine installation may exceed the 25 to 28 per cent thermal efficiency based on power output only. In some cases the local power rates may be sufficiently low as to make the additional cost of installing an engine unattractive. Its installation would probably be unwarranted in very small plants, where the power demand is small and an operator is not on duty at all times.

It is possible to estimate power available by a consideration of the strength of the sewage and the per cent removal. Thus, with primary treatment the average power that can be developed will vary from 5.6 to 29.4 brake horsepower per m.g.d. with 100 p.p.m. and 350 p.p.m. suspended solids in the raw sewage, respectively. These figures are based on 40 per cent removal for the weaker and 60 per cent for the stronger sewage. A volatile solids content of 70 per cent is assumed, of which 60 per cent are digested with a production of 16 cu. ft. of gas per pound of volatile matter. Gas consumption figures are based on 600 B.T.U. per cu. ft. and 10,000 B.T.U. per horsepower hour. With activated sludge treatment, assuming 90 per cent removal for all sewage strengths the power figures would be 12.6 and 44.1 brake h.p. per m.g.d.

With these data available it is possible to estimate what proportion of the power load can be handled by engines. Curves may be constructed which show the power available with different strengths of sewage, and the power required for sewage pumps at various heads and pump efficiencies. Curves for blowers can likewise be constructed which show the power required with various rates of air consumption and tank depths.

At plants where digested sludge is heat dried or burned the heat requirements are so great that engines are not usually considered. With heat drying, assuming 70

per cent cake moisture, from 60 to 95 per cent of the gas produced is required as fuel. Incineration may be self-sustaining, but with wet cake 70 to 90 per cent of the gas may be required as auxiliary fuel.

In general there are two types of installations, those at which engines are used to generate electricity and those where they are used to drive large equipment such as sewage pumps and blowers. Choice may depend on the type of stand-by power available. In New York City some plants have a connection with the gas utility. At other places the generators are tied in with the power company lines and during off-peak conditions may feed power into the company lines. In some instances a diesel engine generator set may be found desirable as a source of stand-by power.

The dual fuel engine, a recent development, is of importance to sanitary engineers. It burns either gas or fuel oil, on the diesel cycle, and can be switched from one fuel to the other without shutting down or losing speed.

By utilizing jacket water heat and exhaust gas heat the usable power and heat recovered may be raised to 75–80 per cent of the input. The details of heat recovery for heating buildings and digestion tanks are many. Additional cooling provisions for jacket water for the engines may be required for the warmer months.

T. L. Herrick

**Disposal Plant to Alleviate Boston Harbor Nuisance.** By Karl R. Kennison. *Civil Engineering*, **16**, 254–57 (June, 1946).

Boston Harbor receives an average of over 250 m.g.d. of raw sewage daily through three outlets. These are as follows: 1. The Moon Island outlet which is located in about the center of the inner harbor. It serves the old main drainage system of the city of Boston. Sewage is discharged only on the outgoing tide. 2. The Deer Island outlet which discharges into the main channel entering the inner harbor, the discharge being continuous. It serves the North Metropolitan system. 3. The Nut Island outlet, serving the South Metropolitan system. The discharge here is also continuous.

Investigations of harbor conditions have been conducted by the State Department of Public Health over the past 10 years. A high degree of treatment is not necessary because of the great dilution. Harbor waters have not contained less than 57 per cent of saturation of dissolved oxygen.

In 1941 and 1945 there was appropriated the sum of $15,000,000 for the design and construction of various projects to relieve harbor conditions, among them being the Nut Island sewage treatment works. Briefly, this plant is designed to remove floating solids and grease, to provide 1½ hours sedimentation preceded by 20 minutes aeration, and to reduce bacteria pollution by chlorination of the effluent. Two-stage digestion will be provided, and digested sludge will be discharged through a 12-in. line to an outlet across the deep channel opposite the Deer Island outlet of the North Metropolitan trunk sewer. Plans call for facilities for dewatering not over 10 per cent of the digested sludge.

The plant is designed for a population of 900,000 and an average flow of 112 m.g.d. The maximum design rate is 300 m.g.d. Present flow is about 95 m.g.d. from a population of 700,000.

Mechanically cleaned bar screens with 1½-in. clear openings will be provided ahead of the grit chambers. Screenings will be sorted for removal of glass, metals and the like. Rags and similar material will be flushed around the grit chambers and returned to the sewage flow. The design provides six mechanically cleaned grit channels, each 80 ft. long and 10½ ft. wide. Grit washing and storage facilities will be provided.

Three of the grit chambers are each followed by two comminutors, six units in all. Each of the other three grit chambers are followed by a fine screen with ½-in. clear openings. Ordinarily the three chambers with comminutors will be used. During higher flows—above 140 m.g.d.—additional chambers will be used, and the screenings from the ½-in. racks will be sluiced back to mix with the flow going to the comminutors.

Four low lift pumps will be provided to lift the sewage for flow through the rest of the plant. The pre-aeration units consist of four channels 167 ft. long, 21 ft. wide and about 14½ ft. deep. The detention period will be 20 minutes at the design rate

of 112 m.g.d., and the air capacity will provide 0.1 cu. ft. per gallon at a flow of 144 m.g.d.

T. L. HERRICK

**Practical Aspects of Sludge Treatment at the Yardley Works of the Birmingham Tame and Rea District Drainage Board.** By NORMAN SALT. The Institute of Sewage Purification.*

The method of treating the sludge as required by the encroachment of residential areas and war-time changes in sewage load and operating personnel is described.

The sewage treatment system consists of mechanically cleaned screens, detritus tanks, lime treatment, sedimentation, bio-flocculation and percolating filters. Table I gives the average results of sewage and effluent analyses during 1945 while Table II shows the character and quantity of the sludge removed from the sedimentation tanks.

The sludges from the sedimentation tanks are digested in two stages and dried on open beds. Sludge gas is collected from the primary digestion tanks and used for heating as well as electric power generation. The primary sludge digesters consist of 10 reinforced-concrete, rectangular, flat-bottomed primary tanks, each of 1,000 cu. yd. capacity, well-insulated by earthen banks and fitted with floating, steel gas covers. The secondary digestion tanks consist of 5 open tanks each of 2,000 cu. yd. capacity. The primary tanks are heated by circulation of warm sludge liquor through them. Two non-clogging centrifugal pumps for lifting raw sludge into the primary tanks, pumping digested sludge to the drying area and returning surplus sludge-liquor to the outfall are provided. The primary digesters are 61

* A Preprint. Paper presented before the Midland Branch held at Birmingham, April 9, 1946.

TABLE I. Average Results of Analysis of Sewage and Effluents, 1945
Results Expressed in Parts per Million

| Shaken Sample | Total Suspended Solids | Ammonia N | Organic N | Nitrite + Nitrate N | Oxygen Absorbed | | 5 Day B.O.D. | pH | Iron as Fe |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Shaken | Settled | | | |
| Crude Sewage | 339 | 37 | 18 | | 127 | 79 | 227 | 6.7 | 56 |
| Sewage* after liming, mixed with secondary liquors | 185 | 44 | 17 | — | 137 | 90 | 230 | 7.0 | 44 |
| Sedimented sewage | 151 | 39 | 9 | — | 70 | 61 | 130 | 7.1 | 18 |
| Bio-plant effluent | 87 | 38 | 8 | — | 43 | 41 | 82 | 7.2 | 8 |
| Mixed filter effluent** | 106 | 20 | 1 | 24 | — | 12 | 13 | 6.8 | 1 |
| Final effluent | 48 | 19 | 1 | 21 | 15 | 11 | 21 | 6.9 | 3 |

* Average analyses over a period of 3 months only.
** Settled sample except for total suspended solids

TABLE II.—Sludge Removed from the Sedimentation Tanks in 12 Months
Average Figures for 1943 4–5

| Nature of Sludge | Volume Cu. Yd. | Dry Solids % | Volatile Matter % | Weight of Dry Solids, Tons | Weight of Volatile Matter, Tons | Proportion of Dry Solids as % of Total |
|---|---|---|---|---|---|---|
| Surplus activated | 865,000 | 0.14 | 72.8 | 908 | 662 | 18.0 |
| Manually-cleaned humus | 39,350 | 2.50 | 56.8 | 739 | 419 | 14.6 |
| Mechanically-cleaned humus | 760,000 | 0.08 | 66.5 | 456 | 303 | 9.0 |
| Digestion tank liquor | 92,030 | 0.50 | 63.5 | 345 | 219 | 6.8 |
| Sewage solids, calculated | — | — | 66.8 | 2602 | 1737 | 51.6 |
| Sedimentation tank, mixed | 137,470 | 4.90 | 66.1 | 5050 | 3340 | 100.0 |

ft. by 31 ft. and have an effective depth of 14½ ft. with two 9 in. diameter inlet pipes above the floor. Digested sludge is removed from the bottom by a 12 in. outlet into the secondary tanks.

Of the 5 secondary tanks 3 are used for secondary digestion. One is used as a settling tank for sludge liquor on the heating circuit and another receives surplus liquor as it is displaced from the primary tanks. These are unheated tanks and provide for decanting the supernatant liquor by means of 5 pipes set at 18 in. differences in elevation.

The primary digesters are heated by pumping 100 g.p.m. in the bottom of the primary tank. This is the only method of heating as no coils are provided. The liquor is drawn off at medium depth through a swan-necked overflow with a weir where the supernatant may be readily observed.

The heating sludge liquor is pumped through the heating exchanger which has 2 in. diameter steel tubes. The temperature of the clean water is regulated to 180° F. thermostatically.

Of the total sludge gas collected 42.7 per cent is used for heating sludge. The average composition of the gas is 31.3 per cent carbon dioxide, 67.9 per cent methane and 0.8 per cent nitrogen and it has a gross calorie value of 685 B.T.U. per cu. ft.

During the years 1943–4–5 the average daily yield of sludge gas was 113,200 or 0.78 cu. ft. per capita daily. This production amounted to 5.52 cu. ft. of gas per lb. of volatile matter added or 12.75 cu. ft. per lb. of volatile matter destroyed in digestion.

Of all sludge gas collected 46.7 per cent is used for electric power generation. The power plant has three engines, one single cylinder and two 3 cylinder engines, capable of developing 34, 118 and 150 brake horsepower. The smallest engine is said to have been the first engine to work on sludge gas in Great Britain and is now 25 years old. The largest engine is over 18 years old and the third engine is 8 years old. The plant is entirely independent, there being no standby electrical or gas connections. A dual fuel engine, 275–330 horsepower, is on order and will relieve this situation in the future.

Secondary sedimentation sludge is mixed with primary sedimentation sludge prior to digestion. This load is imposed in rotation on the 10 primary digestion tanks. This method of rotation results in each digestion tank receiving a charge every four or five days. The charge is equivalent to 17 per cent of the capacity of the tank of which 11 per cent takes the place of dense sludge drawn from the bottom of the tank and 6 per cent displaces liquor which is expelled through the swan-necked overflow by the incoming sludge.

During winter time the water content of the sludge is watched closely to conserve heat. The following table gives the statistics on primary digestion tanks.

**Effect of Primary Digestion Tanks in Reducing Volume of Sludge Being the Average Quantities Treated in 12 Months During 1943–4–5**

| Nature of Sludge | Volume Cu. Yd. | Dry Solids % | Volatile Matter % | Wt. of Dry Solids, Tons | Wt. of Volatile Matter, Tons |
|---|---|---|---|---|---|
| Raw Sludge | 137,470 | 4.90 | 66.1 | 5050 | 3340 |
| After Primary Digestion | 86,320 | 4.92 | 55.6 | 3188 | 1773 |
| Liquor Displaced from Primary Tanks | 51,150 | 0.50 | 63.5 | 192 | 122 |

Sludge digestion temperatures vary from 79° to 85° F. depending on the season. As no gas storage is provided gas production is maintained as nearly constant as possible and the principal job of the operating staff in the summer time is to prepare for the critical winter season ahead.

In the secondary digestion tanks further destruction of the organic matter takes place as indicated in the following table.

**Effect of Secondary Digestion Tanks in Reducing Volume of Sludge Being the Average Quantities Treated in 12 Months During 1943–4–5**

| Nature of Sludge | Volume Cu. Yd. | Dry Solids % | Volatile Matter % | Wt. of Dry Solids, Tons | Wt. of Volatile Matter, Tons |
|---|---|---|---|---|---|
| After Primary Digestion | 86,320 | 4.92 | 55.6 | 3188 | 1773 |
| After Secondary Digestion | 45,440 | 8.53 | 51.9 | 2912 | 1513 |
| Liquor Decanted from Secondary Tanks | 40,880 | 0.50 | 63.5 | 154 | 97 |

The calculated retention period of the sludge in the primary tanks is 26½ days while the calculated period in the secondary tanks is 25 days.

Charts are given showing the average monthly as well as the yield and consumption of sludge gas.

RALPH E. FUHRMAN

**Wartime Treatment of Sewage and Sludge Disposal.*** By F. OLIVER, The Institute of Sewage Purification.

The paper is prepared as an introduction to a visit to the works arranged for the members attending the session with an emphasis on war-time changes. During the war the population of Harrowgate increased from 44,500 to 58,000.

At the Southern works the flow increased from 866,000 gal. per day in 1939 to 1,100,000 in 1944 and the liquid sludge produced had increased by over 200,000 tons per year. At the Northern works the increase was 1,121,000 gal. per day to 1,361,000 gal. per day. The practice of sludge lagooning is followed at both works.

At the Northern sewage works war-time construction of a digestion tank was necessary because of acute conditions. In this plant sludge is pumped from the pump well by water-driven ram against a head of 80 feet. The additional tank was necessary because of the increase in sludge production of two to three times at this plant. The difficulties of constructing the new digestion tanks under war-time conditions are described. Since the new digester has been placed in service operating difficulties have been minimized. An electric centrifugal pump will be installed so that either the pump or the ram can be used for elevating sludge to the lagoons.

The reduction in volume given by the digestion tank has greatly simplified and reduced the expense of the sludge disposal operation.

RALPH E. FUHRMAN

**Treatment and Disposal of Waste Waters Containing Chromate.** By J. GRINDLEY. *J. Society Chemical Industry* (Brit.), 64, 339–344 (Dec., 1945).

Methods of treatment of waste water from a factory engaged in tin-plating and assembly of components of radiators were studied. Spent solutions from anodic oxidation, electro-plating and cleaning metals, and condensed spray from exhaust vents of chromium plating baths should not be discharged into streams or sewers, but recovery should be practiced. Waste wash waters, however, contain too small a concentration of chromium for recovery and these can be treated before discharge. A sample of waste wash water from a tank without continuous flow after 2½ days use had the following composition:

pH value—3.1.
Chromate (as Cr)—207 p.p.m.
Sulfate (as $SO_4$)—51 p.p.m.
Copper—31 p.p.m.
Zinc—trace.

The concentration of this sample was ten times higher than wash waters from continuous flow tanks. Accordingly for experimental work the samples were diluted to a concentration of chromate equivalent to about 20 p.p.m. of chromium.

Reduction of chromates was attempted by use of (*a*) scrap steel and (*b*) ferrous sulfate. Waste wash water containing chromate was kept in stationary contact with steel turnings. A complete reduction was obtained in 1 hour at a pH value of 3.0 or less and in 2 hours at a pH value of 4.0. Continuous treatment with steel

* A preprint of paper presented before the North-Eastern Branch, held at Leeds, on April 27, 1946.

turnings in two tanks in series was attempted. The total contact time was four hours but owing to the application of waste water only during a part of the day, some of the waste was in contact for about 19 hours. With an initial pH value of 4.3 to 5.2 the residual chromate after treatment for 4 hours was 4.3 p.p.m. With a pH value of 3.0–3.1 the residual chromium was 2.0 p.p.m. after a similar period. When the pH value of the untreated waste was 2.8 a trace of chromate remained unreduced after 3 hours.

In an acid solution chromate is reduced to trivalent condition 16 gm. of $FeSO_4 \cdot 7H_2O$ being required to reduce 1 gm. of chromium. In the absence of sufficient acid some chromic hydroxide and ferric hydroxide are produced. Various dosages of ferrous sulfate varying from 1 to 2 times the theoretical value were added to waste with a pH value of 4.1, the liquid stirred to dissolve the ferrous sulfate and then allowed to stand undisturbed up to 19 hours. They were made alkaline with calcium hydroxide and the filtrates examined for chromate. Results showed that the theoretical dose of ferrous sulfate reduced the chromate to a value of 0.3 p.p.m. in ½ hour. For complete removal of chromate in a short time twice the theoretical dose was required. Initial chromate concentration as high as 530 p.p.m. chromium was effectively treated by ferrous sulfate additions. The advantages of reduction by ferrous sulfate treatment are: (*a*) comparative cheapness, (*b*) availability of ferrous sulfate, and (*c*) applicability of the method to both alkaline and acidic waste waters.

Precipitation of chromates with soluble salts of silver, barium and lead under neutral or alkaline conditions is theoretically possible, but due to the toxicity of these salts and their cost, the method is not practical. The process has to be operated by a skilled worker. Experiments were made with witherite a natural barium carbonate. This salt although sparingly soluble in water, is more soluble than barium sulfate or barium carbonate.

Samples of waste water containing chromate were agitated with witherite and then allowed to settle. Complete precipitation of chromate when present initially in 20–278 p.p.m. was obtained with a large excess of witherite at 20° C. and with pH values of wastes varying from 6.9 to 7.4. When stirring was interrupted a yellowish precipitate settled fairly rapidly but the supernatant liquid remained cloudy for about 2 days; after standing quiescent for four days, the supernatant was clear and colorless. Treatment of the supernatant with alum shortens the period required for clarification.

Absorption methods utilizing ion exchangers such as Zeo-Karb and Deminrolit B were tried. These materials completely removed the chromate but attempts to recover the chromium and regenerate the bed with hydrochloric acid and ammonium hydroxide solution were unsuccessful.

Twenty p.p.m. of chromium in the form of potassium chromate and potassium dichromate in distilled water was toxic to rainbow trout. Undiluted samples of waste water after treatment with scrap iron or ferrous sulfate followed by lime treatment had no effect on minnows. Treatment with witherite yielded a harmless effluent provided the waste water is free from heavy metals other than chromium and appreciable concentrations of acids whose barium salts are soluble in water. Waste waters treated with ion exchangers were non-toxic to minnows.

H. HEUKELEKIAN

**Disposal of Petroleum Refinery Wastes. I. Industry's Relation to the Problem.** By W. B. HART. *Nat. Pet. News*, 38, Sect. 2, R11–16 (January 2, 1946).

The disposal of petroleum refinery wastes is a many-sided problem of relationships and methods. These relationships and methods are discussed in a series of articles.

The first article discusses the different effects on the receiving stream of the discharge of sewage and industrial wastes. Although a moderate amount of sewage can be discharged to a stream without permanent effect on the ecology of its flora and fauna, some industrial wastes are decidedly toxic and are rapidly lethal to all forms of aquatic life. A stream may be heavily polluted by sewage without its condition being noted by the untrained eye, whereas many industrial wastes are spectacularly apparent. This contrast in appearance has led to the idea that industrial

waste is the more prevalent, and that industry is the major factor in pollution.

The gradual growth of the stream pollution problem is traced from early days when the general tendency to discard wastes into the nearest body of water caused no nuisance, to the present day when the discharge of wastes from the large concentrations of persons and industries which have developed near streams and lakes can no longer occur without serious damage resulting.

In 1924, the Federal Oil Pollution Act was passed; it was the first real anti-pollution law. Although aimed principally at vessels discharging oil it spurred the refinery industry to make a survey of its wastes through several A.P.I. committees which recommended the appointment of technical groups to devise methods for pollution prevention.

Had waste treatment equipment been installed at an industry before the stream became overloaded the installations could have been paid for out of income; as waste volumes increased, plants could have been extended or modified without imposing a serious expense. Now, costly complete plants will be necessary which frequently will have to be paid for in a relatively short time.

**II. Industry and the Authorities.** By W. B. Hart. *Nat. Pet. News*, 38, Sect. 2, R97–102 (Feb. 6, 1946).

This article discusses the various laws and the agencies that administer them.

In practically every instance where there has been an abuse, such as of some natural convenience, laws to control or eliminate that abuse have been enacted. Laws for the control of stream pollution have been passed by the Federal government and by most of the states.

Federal laws are administered by the Army Engineer, under the Federal Act of 1899, and by the U. S. Coast Guard, under the Oil Pollution Act of 1924.

The Army has divided the country into districts, each supervised by a District Engineer. The Coast Guard likewise separates the country into areas with a supervisor in charge of each. A refinery located on a stream will be responsible to both for oil pollution, and to the former for discharges causing shoaling, as well; neither pays any attention officially to other types of pollution.

Lack of knowledge of the law cannot be construed as part of an effort to obey them, nor is it helpful in relations with the authorities, which experience has shown to be of paramount importance. Co-operation with state agents has proven to be beneficial.

**III. Refining Industry Has Important Role in Water Conservation Program.** By W. B. Hart. *Nat. Pet. News*, 38, Sect. 2, R225–227 (March 6, 1946).

General discussion.

**IV. Proper Classification of Wastes First Step in Disposal Program.** By W. B. Hart. *Nat. Pet. News*, 38, R292–300 (April 3, 1946).

Organized information on the kinds of waste, and on the processes producing them, must be available before the refinery waste disposal problem can be understood. The principal characteristics of these wastes depend largely on the processing methods employed, but it is better to classify wastes by type than by process. Such a classification would include uncontaminated cooling water, storm water, oils and emulsions, acid and alkaline wastes, oxygen consuming matter, wastes causing tastes and odors, toxic substances, waters with high dissolved solids, wastes with suspended solids, colored wastes, semi-solid and solid wastes, and minor miscellaneous wastes. Although considerable overlapping will be found among these general types, the wastes should be classified according to their major characteristic.

Under normal conditions 85–95 per cent of the water consumed in refineries is used for cooling, and it is discharged practically unchanged in quality except for increase in temperature. Such water should be discharged to a separate sewer to avoid contaminating it. Where water is scarce, and cooling towers are used, little uncontaminated water is wasted. There is no relationship, for the industry as a whole, between crude oil processed and cooling water discharged. Total waste water will range from 20 to 1,000 gallons per barrel of crude run.

Storm water, at times, makes up a large part of refinery waste water and often pre-

sents difficult problems in surface water protection. Waste treatment is affected by the volume and rate of run-off of storm water, and this factor must be evaluated for each refinery.

Refinery waste treatment should be based on the assumption that there is no such thing as waste oil; that it becomes waste only through carelessness, unavoidable accident, lack of foresight, or particular process requirement. Oil is too valuable to waste in any form, but experience shows it to be a universal waste throughout the refinery; it appears in all grades from gasoline to asphalt and fuel oil. Waste oil usually arises from spills or leaks, especially where frost penetration causes heaving of pipelines. When oil flows over the ground some evaporates, some penetrates the soil, and some flows to a lower area. Where oil flows off refinery property it usually causes public relations problems; where it flows to the refinery drainage system it must be separated before the waste waters can be discharged or treated further.

Whenever oil and water come together there is danger of emulsion formation; all that is needed is an emulsifying agent and agitation, both of which are usually present in refining drainage systems. Where water-in-oil emulsions are formed, the oil is the continuous phase and the emulsion will not mix with water wastes. These emulsions float on the water surface and are usually held together by a skin-like structure which is often strengthened by fine particles of coke, silt, asphalt, or iron sulfide. When the confining septum is ruptured, the emulsion will generally separate into practically clear water and free oil; such emulsions can be broken readily by mechanical or chemical treatment. Water-in-oil emulsions occur in sewer flows, crude oil storage tank bottoms, lubricating oil processing, acid hydrolyzing and sludge decomposition units. Average composition of a number of these emulsions was 80 per cent oil, 18 per cent water, 1.5 per cent coke and iron sulfide.

Oil-in-water emulsions will mix in all proportions with water, because water is the continuous phase. They have a range of color from milky white to simple opalescence, depending on the degree of dilution. They are relatively stable and usually pass unbroken through gravity separators. Where sufficiently diluted by surface water these emulsions finally break and leave a decided film of oil on the water surface. Oil-in-water emulsions originate in light oil and lubricating oil processing plants, in the hot wells of barometric condensers, where steam traps discharge into sewers carrying oily wastes, and in barrel washing plants. It has been concluded by many that because the oil in these emulsions cannot be seen, none is present. By analysis, however, they have been shown to contain up to 30,000 p.p.m. of oil.

Aqueous acid wastes predominate at many refineries. They originate principally in the treatment plants, acid recovery areas, alkylation units, some water treating plants, and in some special product operations. They result from washing products which have been acid treated, from leakage and spills around such plants, and from careless storage of acid sludges. Sulfuric acid is the usual source of acidity, but at certain refineries hydrofluoric, hydrochloric (from hydrolysis of aluminum chloride), phosphoric (from catalyst pellets), sulfurous, and carbonic acids are important.

Alkaline waste waters occur where alkalies are used for acid neutralization, for removal of hydrogen sulfide, and as anti-corrosion agents. Alkalinity is generally due to sodium hydroxide, sodium carbonate, ammonium hydroxide, and sometimes lime. Alkalinity is usually not as important as acidity, but under certain conditions it may cause serious difficulty.

Oxygen consuming wastes present difficult problems at refineries. Probably the greatest source of such wastes occurs where hydrogen sulfide and mercaptans are scrubbed from crude oil, and some intermediate products, with caustic. This waste is highly toxic, colored, and a source of tastes and odors. Where oils high in sulfur are scrubbed, the waste caustic will contain about 0.3 per cent residual caustic soda, a series of oxysulfur compounds, phenols, mercaptans, naphthenates, and various other organics. This waste may have a 5-day B.O.D. as high as 200,000 p.p.m. Much of the demand is chemical, and oxygen is taken up quickly; fortunately, these wastes occur only in relatively small quantities.

A number of other refinery wastes have an oxygen demand, such as waste from gas washing units, sulfonated oils from acid treatment, leachings from acid sludge, water which separates from crude and certain distillates, and where barrels which had contained animal or vegetable oils are washed.

The outstanding taste and odor producing wastes are those produced where oils are scrubbed with caustic. Some of these may have threshold values as great as 1 part in 50,000,000 or more. The odor is largely due to complex sulfur and nitrogen compounds. Acid sludges are the next most important in this category. The odor here is due to mercaptans; it is claimed that 1 part of ethyl mercaptan can be detected in 50 billion parts of odor-free water. Water which has been in contact with gasoline and certain other stocks has a pronounced odor, but it is dissipated readily by aeration.

Among the most toxic substances in refinery wastes are the mercaptans, naphthenates, complex sulfides, complex nitrogen compounds, certain ammonium salts, water separated from some crudes, and the special organic compounds made at some refineries.

High concentration of dissolved mineral matter is also lethal to aquatic life as a result of osmotic effects. Caustic scrubbing wastes, and the waste from caustic washing of acid-washed products, are highly concentrated solutions of mineral matter. Some crudes arrive at the refinery with considerable quantities of brine, and the separated liquor may contain 50,000 to 250,000 p.p.m. of dissolved salts, mainly sodium chloride.

Refinery waste waters contain suspended matter, consisting of fine sand, coke, lead sulfide, metallic hydroxides, etc., which settle out when the flow velocity drops for any considerable time, as in a gravity separator. Reactions take place between the wastes from different processes, and form precipitates. Certain of these suspended solids are so fine that they will not settle over a long period.

Colored wastes are produced in caustic scrubbing and acid sludge separation. Minor wastes come from experimental units, gasoline stabilizers, viscosity additives, and a variety of special operations. The semi-solid and solid wastes are acid sludges, spent clay, spent catalyst, tank bottoms and separator cleanings.

This paper includes a comprehensive chart of refinery operations and the wastes produced by each.

**V. Properties of Surface Waters Affected by Refinery Wastes.** By W. B. Hart. *Nat. Pet. News*, 38, R371–76 (May 1, 1946).

This article comprises a brief but comprehensive account of the physical, chemical, and biological nature of surface waters. It provides a background to guide the refinery operator in understanding the possible effects of wastes upon the bodies of water into which they may be discharged. Differences between the environment in flowing streams (lotic) and that in standing waters (lentic) are described. The variety in chemical analysis of surface waters is discussed, and oxygenation and deoxygenation are treated in some detail. A fundamental view of hydrobiology, including a description of the zones of degradation, decomposition, and recovery, is given because of its importance to the treatment plant operator. There are five physico-chemical tables.

**VI. Waste Oils Escaping to Surface Waters May Cause Many Kinds of Damage.** By W. B. Hart. *Nat. Pet. News*, 38, R467–73 (June 5, 1946).

Uncontaminated water which passes through cooling coils in a refinery differs, when discharged, from its original state in several particulars. Cooling waters range in temperature from 85° to 115° F., and while some surface waters have temperature ranges in excess of this, the upper limit is usually below the lower limit of cooling water. Where cooling water is discharged to a large body of water its temperature may have only a small effect, but increases in temperature, if sufficiently great, may affect aquatic life seriously. Most of these forms of life can exist only in relatively narrow temperature ranges, and when the upper temperature limit is exceeded for only a very short time, death will ensue.

Discharged cooling water may contain little or no dissolved oxygen because of the lower solubility of the gas at the higher temperature and the greater bacterial activity which results in rapid oxygen con-

sumption. The effects of low dissolved oxygen (D.O.) may be confined to a small area if there is suitable dilution and mixing, but, if the dissolved oxygen does not rise quickly to 40–50 per cent of saturation, no aquatic life will be present in the mixture of cooling and surface water. The B.O.D. of the discharged water may be reduced practically to zero, due to increased bacterial activity.

Some surface waters are so corrosive that the cooling water will pick up heavy metal ions in its passage through the coils. This may result in concentrations harmful to aquatic life.

A heavy run-off of surface water will sometimes overload sewers and treatment plant to such an extent that they will pass the plant without treatment. These waters carry such a heterogeneous mass of substances that their effects cannot be predicted. Where damage occurs to the receiving stream or lake it is difficult to decide which particular waste was responsible. More important, however, is the extent of the damage which may result. A refinery may have spent thousands of dollars on a waste treatment plant and and may have brought the surface water back from a highly polluted state to one of cleanliness. Then, as a result of the escape of pollutional substances with the storm run-off, all aquatic life can be destroyed, dissolved oxygen eliminated, and the further use of the water affected. It may take several years for the water to recover.

Where oil is spilled on the ground, the relative degree of vaporization and penetration will depend on the oil viscosity, type of soil, and temperature. Even light oils coat and kill vegetation, and various plant forms caught by the penetrating oil are destroyed; some of these are vitally important to soil productiveness. Oil which continues to penetrate the soil is lasting in its effects by interfering with the penetration of air and the distribution of water. Where a single spill has occurred the soil will gradually return to normal productiveness through the effects of rain and the action of soil bacteria, but several years may be required for this result. Continued spills can prevent growth forever.

If oil is spilled on a water surface it spreads out rapidly and forms a thin film. Winds tend to break the film into patches, and these accumulate dust and debris until they eventually gain enough density to sink. But where winds drive the oil into a shoreline indentation or other barrier, the film will become much thicker and it will resist disruption for a long time. An oil film 0.0000015 in. thick is barely visible; a film 0.00004 in. thick usually disappears in less than a day. Bacterial action in the ooze or sludge on the bottom finally oxidizes and destroys the oil which has settled.

Oil does not disappear from the surface of water bodies before causing damage. Films collect on structures to form a sludgy layer which is not only unsightly but harbors bacteria which often are detrimental; the sulfur compounds are converted to sulfuric acid, causing corrosion. Oil destroys aquatic vegetation, removing protection from the young of valuable fish which then become an easy prey for predator forms. Oil coats the gill tissue of fish and causes death by asphyxiation. Even thin films are destructive to surface feeding fish. Many valuable fish nest in shoreline shallows; oil destroys these nesting areas.

A shoreline degraded by floating oil is unstable because the oil coats and kills the roots of the plants which protect the banks against erosion. Recreational areas are seriously affected. Shore birds and shell fisheries have been destroyed. Oils contribute tastes and odors which often carry through the water putrification plant. Crude oils contain soluble compounds which are toxic.

It has been claimed that floating oil is a serious obstacle to gaseous interchange at water surfaces and undoubtedly this is true where oil blankets the surface of still water. But aeration is so much more dependent on photosynthesis and wave action than on quiescent surface absorption that this effect of oil would seem to have been overemphasized in the past.

RICHARD D. HOAK

---

**The Effect of Mining (Coal) Subsidence on Sewers and Sewage Disposal Works in the West Riding of Yorkshire.** By J. H. GARNER. Report to West Riding of Yorkshire Rivers Board, pp. 35 (December, 1945).

The difficulties experienced at the sewage works of the Barnsley Corporation as a

result of coal-mining subsidence during about 20 years created a demand for a survey to be made throughout the West Riding of Yorkshire Rivers Board Region of damages to sewers and sewage works caused by coal-mining subsidence. Copies of the two kinds of questionnaires, (*a*) effects of mining (coal) subsidence on sewers; and (*b*) on sewage works are included in the Report. Replies are recorded from 66 sewage works in the 26 Districts. Among the questions asked were the following: place and size of sewers affected; nature and extent of damage; cost of repairs; date or period of subsidence; has subsidence ceased, is it likely to recur if other seams are worked; has any compensation for damage been received; to what extent has subsidence interferred with proper operation of the sewage works; and other particulars worth recording.

Types of damages reported were: broken sewer lines, cracks developed in walls and floors of filters, settling tanks and filter effluent channels. Diminishing the gradient even in some cases to reversing the flow, back falls, and danger of flooding from the river were mentioned as results of subsidence. Temporary expedients adopted included installation of pumps, more frequent flushing or dragging of the damaged sewers, temporary by-pass lines or masonry construction and more permanent repairs such as relaying sewer lines.

Cost to repair damages varied from £15 to an estimated £22,000 where an extensive sewerage system had to be relaid. Other rather large costs reported were £2,500, £4,300, £5,400. Many cases of costs of damage reported ranged from £15 to £350. There were several sewage works which reported no damage and only four where any compensation had been received. A number of replies stated that no separate record had been kept of damage due to subsidence. Permanent repair and reconditioning of works and plant cannot be satisfactorily carried out until subsidence has ceased. Where the coal seam mined is deep (820 yards deep in one district) no signs of subsidence effect have developed to date.

In recent times in districts where subsidence is likely to occur the engineers have realized, and the Ministry of Health have insisted upon, the necessity for adopting special methods of construction of sewers and sewage works. In general by careful selection and adoption of suitable methods of design and construction, damage and interference with works of sewerage and sewage disposal can be reduced to a tolerable limit.

W. W. Horne

**Industrial Waste Problem to be Solved.** *Public Health News*, N. J., 28, No. 3, 92-93 (1946).

The waste produced by National Lead Company in Sayreville, N. J., located on the Raritan River, contains 3,000 tons of dilute acid waste and appreciable amounts of copperas. It has been proposed to discharge these wastes into the ocean by a tanker. A plan has been worked out by Fish and Wildlife Service, Atlantic States Marine Fisheries Commission and the Company to discharge the wastes 14 miles southeast of Scotland Yard in an area of two square miles. Opinion of experts was that that hazard to commercial and sport fishing in this area would be insignificant. Dumping during the winter will be permitted at a more inshore location and at the surface. During the summer or in periods of calm a more offshore location will be used along with disposal beneath the surface.

H. Heckelekian

**The Preparation and Nature of Town's Refuse-Sewage Sludge Composts.** By C. Bould. Presented before the Institute of Sewage Purification, November 30, 1945.*

This paper reports the results of investigations on the preparation and nature of composts made from refuse and liquid sewage sludge.

Pulverized refuse was placed in cells and the surface of the refuse formed into a shallow lagoon. Cells used were 5 ft. by 5 ft. by 4½ ft. deep. Walls and base were of concrete and front was made of 2 in. thick boards. Sludge was then added and covered with some of the refuse from the walls of the lagoon. After the surplus water from the sludge was absorbed (three to four days time required if refuse is not

* A preprint.

**TABLE I.—Chemical Analysis of Some Samples of Pulverised Town's Refuse Used in the Maidenhead Experiments**

| Date of Sampling | % Fresh Wt. | | As Per Cent Dry Matter | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture | Dry Matter | Total N | Ammonia N | Residual N | Total C | Residual C | Total C:N Ratio | Corrected C:N Ratio | Total $P_2O_5$ | Total $K_2O$ | Total Ash | Loss on Ignition | Cellulose |
| 7-15-41 | 34.6 | 65.4 | 0.963[a] | — | 0.173 | 26.17 | 6.52 | 26.3 | 24.0 | 0.749 | — | 47.2 | 52.8 | 16.5 |
| 10-10-41 | 47.0 | 54.1 | 1.022[a] | — | — | — | — | — | — | 0.885 | — | 46.7 | 53.3 | — |
| 7-23-42 | 38.0 | 62.0 | 1.181 | 0.118 | — | — | — | — | — | 0.680 | — | 60.0 | 40.0 | — |
| 8-20-45 | 33.7 | 66.3 | 1.103 | 0.119 | — | — | — | — | — | — | 0.541 | 53.4 | 46.6 | — |

[a] Does not include ammoniacal nitrogen which was lost on drying.

**TABLE II. Chemical Analysis of Some Sewage Sludges Used in the Maidenhead Experiment**

| Date of Sampling | As Per Cent of Fresh Wt. | | | | | | Total C:N Ratio | pH | Ether Sol. Matter as Per Cent Dry Wt. |
|---|---|---|---|---|---|---|---|---|---|
| | Water | Total Solids | Total N | Ammonia N | Organic Carbon | Total $P_2O_5$ | | | |
| 5-21-42 | 94.5 | 5.5 | 0.204 | 0.014 | 2.24 | 0.082 | 11.2 | 5.9 | — |
| 7-28-41 | 94.5 | 5.5 | 0.181 | 0.019 | 2.14 | — | 11.8 | 6.6 | — |
| 10-16-41 | 94.7 | 5.3 | 0.198 | 0.017 | 2.29 | 0.078 | 11.6 | 6.0 | — |
| 6-10-45 | 93.5 | 6.5 | 0.265 | — | — | 0.139 | — | — | 26.4 |

consolidated), the cells were emptied and the materials thoroughly mixed and replaced.

The chemical analysis of refuse and sludge used are given in Tables I and II.

Sludge was added in varying amounts, so as to bring the final moisture content to 50, 60 and 68 per cent, respectively. The following results were noted:

"Composts with original moisture content of 50 and 60 per cent (fresh weight) had a good texture, were free from smell and the condition was such that they could be bagged (moisture content = 32 per cent). Compost with an initial moisture content of 68 per cent appeared "sticky" when sampled and smelt strongly of sludge. The stickiness was still noticeable after fourteen weeks."

"Temperatures of composts with original moisture contents of 50 and 60 per cent rose rapidly, reaching a maximum of 76° C. three days after mixing, whereas the temperature of composts with 68 per cent moisture did not exceed 55° C."

*Aeration.* Aeration was accomplished by two methods. "Method 1 was to cover the base of the cells with a continuous layer of 3 in. land drain pipes, and method 2, as in 1 only using filter bed tiles, or tiles so placed as to form channels 2 ft. apart." Both methods were satisfactory as far as aeration was concerned, but it is stated that the pipes and tiles would be too fragile for commercial purposes. It is recommended that channels about 9 in. wide by 6 in. deep be sunk into the concrete base of the cell, and covered with an iron grid with a 1 in. mesh. Free access to air for these channels should be provided.

*Addition of Chemicals to Composts.* Addition of nitrogen as ammonium sulfate dissolved in the sewage sludge, so as to give an addition of 0.1 per cent nitrogen on the basis of dry weight of refuse, caused a rise in temperature of 3 to 4° C. in aerated composts. No effect was noted on non-aerated composts. As judged by total loss of dry matter the addition of nitrogen had no significant effect on rate of decomposition.

Addition of phosphate as mono-calcium phosphate added to the sewage sludge so as to give 0.2 per cent $P_2O_5$ on the basis of dry weight of refuse produced a small positive effect on the rate of decomposition over a period of two weeks.

*Nitrogen Changes During Decomposition.* The relative contribution by the refuse and sludge to the dry matter and nitrogen is shown in Table III. The changes in nitrogen content of composts during decomposition are shown in Table IV.

TABLE III. Contribution of Dry Matter and Total Nitrogen to Composts by the Refuse and Sludge

| Original Moisture Content as Per Cent Fresh Weight | Fresh Wt. Ratio Refuse/ Sludge | Dry Wt. Ratio Refuse/ Sludge | Nitrogen from | | Total N Lb. | Total Nitrogen | |
|---|---|---|---|---|---|---|---|
| | | | Refuse Lb. | Sludge Lb. | | Per Cent Dry Wt. | Per Cent Loss on Ignition |
| 50.0 | 3.5 | 82 | 20.37 | 0.87 | 21.24 | 1.215 | 3.02 |
| 60.0 | 1.5 | 34 | 19.47 | 2.06 | 21.53 | 1.268 | 3.12 |
| 68.0 | 0.95 | 20 | 20.05 | 3.62 | 23.67 | 1.327 | 3.23 |

TABLE IV. Changes in the Nitrogen Content of Refuse-Sludge Composts During Decomposition

| Original Moisture Content as Per Cent Fresh Weight | Period of Decomposition in Weeks | As Per Cent Dry Wt. | | Total N as Per Cent of Loss on Ignition |
|---|---|---|---|---|
| | | Total N | Ammonia N | |
| 50 | 5 aerobic | 1.183 | 0.123 | 3.44 |
| 60 | | 1.157 | 0.097 | 3.40 |
| 68 | | 1.111 | 0.139 | 3.95 |
| 50 | 5 aerobic 9 anaerobic | 0.960 | 0.014 | 3.44 |
| 60 | | 1.058 | 0.018 | 3.85 |
| 68 | | 0.875 | 0.011 | 3.09 |

As noted in Table I, fresh pulverized refuse contained approximately 0.11 per cent (dry wt. basis) ammoniacal nitrogen. Within two weeks after sludging, under aerobic conditions, the ammoniacal nitrogen may reach as much as 0.4 per cent dry weight. This ammonia is probably produced by ammonification of proteins in the refuse. Nitrification tests carried out on sludge used showed that nitrogen immobilization took place when it was added to the soil. This is attributed to the high ether soluble fraction, which formed from 26 to 30 per cent of the total dry matter. After removal of this fraction the sludge liberated nitrogen quite readily.

Losses of nitrogen always occurred during decomposition, in some cases amounting to as much as 43 per cent of the total. In order to reduce these losses to a minimum the author recommends that the initial aerobic period should not exceed two weeks. This should be followed by a storage period under partial anaerobic conditions for one to two months, or until tests indicate that the compost is mature.

*Methods for Determining the State of Maturity of Composts.* Considerable time and experimentation were spent on this problem. Methods have been devised or modified to indicate the state of maturity of composts.

"It may be taken that a compost will not immobilize soil nitrogen if it satisfies one or more of the following conditions:

1. The 'corrected' carbon/nitrogen ratio is less than 20.
2. The nitrogen, expressed as a percentage of the 'loss on ignition' is greater than 3.0 per cent. It usually becomes stabilized around 3.5 per cent.
3. When mixed with soil and kept at optimum moisture and temperature conditions nitrates are liberated (nitrification test).
4. When mixed with an equal quantity by dry weight of cellulose, and given optimum conditions of moisture, aeration, and mineral supply other than nitrogen, increased evolution of carbon dioxide takes place (fermentation test)."

*Availability of Nutrients.* Some idea of the chemical composition of refuse sludge composts is given below:

| *Constituent* | *Per Cent of Dry Matter* |
|---|---|
| Total Nitrogen | 0.88– 1.50 |
| Total $P_2O_5$ | 0.83– 1.40 |
| Total $K_2O$ | 0.30– 0.60 |
| Total Ash | 50.0 –60.0 |

Laboratory and pot experiments have shown that the total values for the major constituents—nitrogen, phosphorus, and potassium do not necessarily give a true picture of the manurial value of the compost. Availability of nitrogen in mature composts does not exceed 20 per cent of the total and more often amounts to only 10 per cent of the total.

From results, not yet complete, it appears that availability of phosphorus in some composts is very low.

No pot experiments have been carried out to test potash availability, but solubility studies indicate that perhaps 40 to 50 per cent of total potassium might be available.

*Suggestions for the Layout of a Mechanized Commercial Plant.* In the light of the investigations carried out the author makes the following suggestions to indicate the general lines on which a large scale plant might be constructed:

"1. Particular attention must be paid to the salvage and preparation of a pulverized refuse high in organic matter. After tipping the refuse from collection lorries into hoppers, it should pass into enclosed rotary screens for the removal of fine ash. The size of the mesh might have to be changed with the seasons. A useful size for removal of fine dust would be $\frac{3}{8}$ in. mesh.

"2. After screening, the refuse should pass on to conveyor belts, where salvage of large paper, rags, bottles, wood and metals should take place.

"3. The refuse should then be pulverized in some form of crusher, but not too fine as to impede aeration.

"4. Some attempt should be made, either before or after crushing, to separate larger particles of coke, coal, and mineral matter from the vegetable matter. It has been suggested that this could be accomplished by allowing the material to fall on to a conveyor belt, the angle of which from the horizontal could be adjusted so as to retain the flat organic matter and cause the heavier rounded particles of mineral matter to fall off.

"5. Control should be exercised over the proportions and sludge used. The pulverized refuse might first be fed into a hopper of known capacity.

"6. The refuse and sludge should be intimately mixed in a mechanical mixer prior to being transported to the aeration cells.

"7. Cells constructed of concrete, or brick, should be provided with aeration channels in the floor. Until more information is available the depth of the cells should not be much greater than five feet if natural under-aeration is employed. The cells should be large enough to take the maximum supply of refuse for one to two days. Assuming a six-day working week, and an aerobic period not exceeding two weeks, then seven or more cells would be required. The last cell would be in the process of being filled whilst the first one was being emptied.

"8. Adequate storage space should be available for maturing the compost, preferably under cover. No definite rules can be laid down with regard to the length of this second period since the demand for compost would be greatest in Autumn and Spring. Since the availability of the nitrogen in mature composts is low, in certain cases better results might be obtained by using the compost whilst the ammoniacal nitrogen content is high, but more information is required on this point before it can be recommended."

GERARD A. ROHLICH

**The Failure of Poliomyelitis Virus to Grow in Certain Protozoa of Sewage.** By C. A. EVANS AND K. L. OSTERUD. *Science*, 104, No. 2690, 51–53 (July 19, 1946).

The possibility of the growth of poliomyelitis virus on sewage profozoa was investigated. Surface waters from various sources and sewage containing protozoa were inoculated with the virus. Weekly transfers were made to freshly collected uninoculated waters. Inoculation into monkeys showed that the virus had failed to develop. Similar work with cultures of protozoa was undertaken. Bodo was selected as the protozoa most commonly present in sewage treatment systems. In addition Monas, Oikomonas, Tetrahymena, Cronema and Pleuromonas were also tested. The protozoa were grown on wheat extract and the virus was added to the cultures, incubated and transferred. Samples of fluid taken from the third set of cultures were inoculated into monkeys. The results were negative. It was concluded that naturally occurring neuro-organisms in surface waters failed to yield a significant increase in several strains of poliomyelitis virus and that the protozoa tested failed to support the growth of virus.

H. HEUKELEKIAN

**Control by D.D.T. of Flies Breeding in Percolating Sewage Filters.** By T. G. TOMLINSON. *Nature*, 156, 478–79 (October 20, 1945).

Experiments on the treatment of small experimental filters with D.D.T. in the

form of (*a*) a powder applied at the rate of 300 lb. per acre, and (*b*) an emulsion of D.D.T. in naphtha or kerosene at a rate of application of 50–100 lb. of D.D.T. per acre showed that more than 90 per cent of the larvae of *Anisopus* and *Psychoda* were killed and that the Collembolla and enchytraeid worms were unaffected. D.D.T. in these concentrations is non-toxic to bacteria and fungi in the filter, and thus has no deleterious effect on purification. Treatment with creosote (400 gal. acre) gave the greatest reduction in numbers of *Anisopus* but all the scouring organisms in the filter were killed. Bleaching powder ($6\frac{1}{2}$ tons per acre) caused the biological film to be discharged.

H. HEUKELEKIAN

**Investigation of Plant Growth Substances (Auxins) in Sewage Products.** By C. A. CHAPLIN AND C. J. REGAN. *J. Society Chemical Industry* (Brit.), **64**, 331–32 (December, 1945).

The heteroauxin ($\beta$-indolylacetic acid) content of fresh urine and of effluent and of raw digested and composted sludges was determined. The only sewage products yielding a determinable quantity was fresh raw sludge which contained .05 p.p.m. The total auxins were also determined. There was appreciable variation in the total auxin content even for the same type of sewage material. Fresh raw sludge had the highest total auxin content with .38 p.p.m. However, 90 per cent of the auxin content is destroyed during air drying. Activated sludge had a lower total auxin content than fresh sludge.

H. HEUKELEKIAN

**Grand Forks Water and Sewage.** By K. W. RILEY. *Monthly Bulletin, North Dakota Water and Sewage Works Conference*, **13**, 2–4, No. 1 (July, 1945).

This article, written for the general public, briefly describes the water purification and sewage treatment facilities at Grand Forks, North Dakota.

The sewage treatment plant, placed in operation in February, 1937, consists of coarse screens, a pre-aeration tank, plain sedimentation tanks and separate sludge digestors. Gas is collected and used to heat sludge digestion tanks and buildings. Provision for addition of flocculating chemicals has been made, but to date has not been used, since it has been found that precipitated sludge from the city water treatment plant creates a rapidly settling floc at the sewage treatment plant clarifiers.

Average sewage flow during 1944 was 51 gallons per capita per day. Results of treatment showed removal of 99.9 per cent settleable solids and 32.6 per cent B.O.D.

GERARD A. ROHLICH

**Modern Design Trends for Sewage Treatment.** By KENNETH V. HILL. *Monthly Bulletin, North Dakota Water and Sewage Works Conference*, **12**, 5–8, No. 12 (June, 1945).

Ten factors influencing the trend in the design of sewage treatment plants are discussed.

1. The War: Construction and operation of sewage treatment plants by the Army and Navy has stimulated interest in sewage treatment. In several states the treatment plants, built by the Services, are pioneer installations. In some cases the Army and Navy have contributed financially to the cost of enlargement of municipal sewage treatment works, in which Service sewage was to be treated.

   Operating data on high rate filters, unheated sludge digestion tanks, sewage ponds and grease removal devices has been gained at military establishments. Some information on laundry wastes has been obtained.

   A committee of military and civilian personnel are making a survey of operation of sewage treatment plants at military establishments, and the reports of that committee may provide operation data on certain devices about which comparatively little factual data now are available.
2. Research: The importance of research as an influence upon the design of sewage treatment plants is stressed.
3. Governmental Influence: Present indications are that governmental influence, exerted principally through financial aid to municipalities undertaking the construction of sewage treatment works, will be continued.

War Mobilization and Reconversion Act, Title V, Public Works provides for loans to political subdivisions to aid in financing engineering and architectual costs for planning the construction of public works.

The Government's interest in sewage treatment is further evidenced by the work of the Corps of Engineers and the Public Health Service in a survey and report on pollution control of the Ohio River and tributaries.

4. Industrial Waste Treatment: Present researches on industrial waste treatment will have a direct bearing on sewage treatment plant design.
5. Patented Processes: The majority of sewage treatment process patents are held or controlled by manufacturers of mechanical equipment. In general, fees are nominal and included in the equipment cost. Inasmuch as not all manufacturers are licensed under all patents, designing engineers are restricted somewhat in the choice of equipment and competition in the purchase of equipment is somewhat restricted.

Patents held and controlled by individuals and not proven in practice are to be used warily.

6. Handling of Garbage with Sewage: There are some dozen installations which combine the disposal of garbage with sewage. In most of these installations the garbage is ground and added to the sewage solids for digestion and disposal only.

While garbage disposal by use of built-in sink grinders is attractive and aesthetic, from the viewpoint of the householder, recognition of first cost and maintenance of such grinders should be given proper consideration.

Where garbage and refuse are collected at the same time, by the same truck and crew, economy of garbage disposal through sewers merits careful study, since cost of collection and disposal of rubbish alone might be almost as much as cost for combined collection and disposal.

Treatment of garbage solids alone with sewage solids in the digestion process appears more promising than treatment of garbage with sewage.

7. Combinations of Processes and Stage Treatment: Combined biological filtration and aeration units in series or filters in series are better adapted for handling strong sewages, and because of the increasing treatment of industrial wastes in sewage plants it is the author's belief that combination or stage treatment methods will receive increased consideration in future designs.
8. Greater Use of Mechanical Equipment: The convenience and labor saving features of mechanical devices, as well as improvement in manufacture, will bring about increasing use of mechanical equipment at sewage treatment plants.
9. Development of Resources in Sludge Solids: It is probable that increased use will be made of sludge gas for power development and for heat drying and incineration.

The importance of sludge as a soil conditioning agent is stressed.

10. Regional Development of Sewage Treatment: "The principal objective of regional development of sewage treatment is to maintain a given waterway in a satisfactory condition throughout its entire course, so as to guarantee to every municipality a reasonable and proper use of the water."

This policy has been followed in some states in this country, notably Wisconsin and Illinois. There is a trend toward interstate compacts to deal with pollution of interstate waters, but none of these compacts are old enough to prove the success of this method of dealing with pollutional problems.

GERARD A. ROHLICH

**Washington State Sewerage Systems and Sewage Treatment and Disposal Systems.** Prepared by: Division of Public Health Engineering, Washington State Department of Health. *Water Supply and Sewerage News, Washington State Department of Health*, **9**, 1–18, Nos. 11 and 12 (November and December, 1944).

A census of sewerage and sewage treatment plants and disposal systems in the state of Washington is presented.

It is stated that the tabulations of sewerage data include all communities having

organized sewer systems serving a resident population of 100 or more people. Included also are data on institutional, industrial, war housing projects and other semi-public systems. Systems serving Army and Navy establishments were omitted for security reasons. The compilation of data covers a total of 162 systems.

The following table gives the status of sewerage and sewage treatment and disposal for the period 1933–1944.

**Status of Sewerage and Sewage Treatment and Disposal 1933–1944**

| Year | State Pop.* (in thousands) | Populated Areas Pop.† (in thousands) | Pop. Served by Sewers (in thousands) | Pop. Served by Treatment (in thousands) | No. of Treatment Plants‡ |
|---|---|---|---|---|---|
| 1933 | 1,620 | 1,000+ | 705+ | 59.1 | 34 |
| 1934 | 1,640 | 1,011§ | 714§ | 59.6 | 36 |
| 1935 | 1,660 | 1,180+ | 723+ | 63.9 | 38 |
| 1936 | 1,680 | 1,026+ | 732+ | 65.9 | 41 |
| 1937 | 1,700 | 1,033+ | 741+ | 89.7 | 45 |
| 1938 | 1,710 | 1,040 | 750 | 93.0 | 49 |
| 1939 | 1,730 | 1,060+ | 778+ | 131.0 | 52 |
| 1940 | 1,740 | 1,081 | 807 | 137.4 | 55 |
| 1941 | 1,820 | 1,156 | 875 | 150.8 | 65 |
| 1942 | 1,890 | 1,233 | 945 | 207.6 | 75 |
| 1943 | 1,980 | 1,380 | 1,067 | 272.6 | 100 |
| 1944 | 2,000 | 1,512 | 1,181 | 325.1 | 117 |
| Future | | | | 671.8‡ | 118‡ |

* Estimates based on treatment facilities for which plans have been, or are being prepared.

* From Division of Vital Statistics, Washington State Department of Health.

† Includes incorporated cities, public housing developments, institutions and industry.

‡ Treatment includes conventional sewage treatment plants, ground absorption, land irrigation, and approved deep water outfall systems.

§ From comprehensive survey by Department of Health in 1934.

+ Obtained by interpolation.

All other figures obtained from Departmental records.

GERARD A. ROHLICH

---

**Current Developments in Waste Utilization.** BY HAROLD R. MURDOCK. *Ind. Eng. Chem.*, 38, 81–2 (advertising section, March, 1946).

This article describes the lack of wood and the studies made to impregnate existing wood with chemicals to improve them. From a third to a half of the wood consumed in the woodworking industry becomes waste and is burned under boilers. Because it is clean lumber it could easily be converted into wood pulp to reduce the overall cost of products; such conversion and use, however, must take place at the point of origin because of transportation costs. Assuming only a 25 per cent waste of wood it has been estimated that by 1950 the potential production of short-fiber hardwood pulp would be 1.5 to 2 million tons. In 1944 the paper industry used only 426,388 tons of short-fiber soda pulp made from hardwood.

An obstacle to this kind of utilization is the small size of the wood plant compared with wood pulp mills. But intense activity is in progress whose emphasis is on high yield pulps. It has been pointed out that molded plastics can be made from high yield wood pulps in which little or no phenolic resin has been incorporated. With a cheap process for manufacturing such pulps from waste wood many small operations within the woodworking industry could become self-sustaining.

*Ind. Eng. Chem.*, 38, 81–2 (advertising section, April, 1946).

This contribution is essentially an abstract of "Treatment and Disposal of Spent Pickling Liquors," THIS JOURNAL, 17, 940–51 (September, 1945).

*Ind. Eng. Chem.*, 38, 83–4 (advertising section, May, 1946).

Chemical engineering appears to have solved the difficult problem of disposing of spent sulfite liquors from the manufacture of sulfite wood pulps. The new process utilizes all of the constituents of the waste liquor directly in the mill producing it.

Approximately 15,700 tons of moisture-free wood is digested each day (300 day year) with an aqueous solution of calcium bisulfite and sulfur dioxide. About 50 per cent of the wood is dissolved in the process. The spent liquor discharged to streams contains about 4,000 tons of lignin sulfonates, 4,000 tons of carbohydrate substances, 2,335 tons of sulfur as calcium bisulfite and sulfurous acid, and 1,175 tons of calcium oxide as calcium bisulfite. This waste has a $B_5O.D.$ of 9 billion, equivalent to a population of 36 million persons.

The spent liquor contains essentially three basic substances—lignin sulfonates, complex carbohydrates, and inorganic cooking chemicals. No process or patent for treating this waste has consumed all of these substances. For example, manufacture of vanillin utilizes only the lignin sulfonate, and a few days' production from a single pulp mill will provide a year's supply of this substance. Other products, such as road binders, linoleum cements, and lignin plastics, use only the lignin fraction of the waste. Similarly, alcohol and edible yeast production uses only the carbohydrate fraction.

Where the liquor is evaporated and used as a fuel, about 12,000 pounds of steam can be made from the liquor from one ton of wood pulp. This process has found little favor because of the corrosiveness of the liquor and the lack of economical by-products other than steam. The inability of the calcium sulfate, formed during the incineration, to decompose to calcium oxide and oxides of sulfur prevents its recovery as a cooking chemical; also, the free sulfur dioxide is seriously diluted with combustion products.

The fact that magnesium sulfate breaks down into the oxide rather than the sulfide has now become the keystone of a new magnesium-base sulfite pulping process. A mill which normally uses 250 pounds of sulfur per ton of pulp would require only 25 pounds of sulfur and 7.5 pounds of magnesium oxide per ton if the new process were installed. At the same time, enough steam and power may be produced to operate the mill.

This is a definite solution to stream pollution from this source and the waste is completely consumed in the mill making it.

*Ind. Eng. Chem.*, 38, 81–2 (advertising section, June, 1946).

The discharge of industrial wastes to a municipal sewer system often places a serious burden on the treatment plant through overloading of the facilities or by introduction of toxic substances which interfere with bacterial action. Past experience has shown that regulation of such discharges is essential to keep the treatment process under positive control. Real difficulties are encountered in smaller cities where trade waste is proportionally substantial.

Co-operation with, rather than persecution of, industry should be the basis for waste disposal. An example is cited where a small community, without co-operating in a study of the problem, prohibited the discharge of potato wastes into the sewer system until the town was indemnified for prior damage claims from this source. As a result, the company closed its plant and moved to another city. In contrast to this lack of foresight, the experience of a similar small town is described in which a leather processing plant was persuaded to install a fine screen to reduce the load on the sewage works. The company found a market for the waste so recovered; it paid for the screen and the operation continues to be profitable.

In recent years there has been increasing recognition of the responsibility of industry to pay a reasonable charge for wastes treated with domestic sewage wherever such wastes place a burden on the sewage plant. These charges vary with conditions, ranging from complete installation of sewage-waste treatment plants plus a contribution toward operating costs, to a graduated charge based on volume, settleable solids, and oxygen demand.

In 1944, New Brunswick, N. J., decided that all wastes should be treated at the municipal plant without pretreatment by industry. Based upon flow, suspended solids, and chlorine demand, the following rates were established: $22.00 per million gallons, $5.00 per ton of sludge, and $5.00 per 100-pound chlorine demand.

In England the responsibility for sewage disposal was transferred from the local authorities to a national board in 1936. Since that time all new discharges of factory effluent to sewers have been assessed on the basis of the actual cost of purification.

*Ind. Eng. Chem.*, 38, 81–2 (advertising section, July, 1946).

Many cities co-operate with industry by treating trade waste with sewage. Where such co-operation is planned, it is important to consider the effects of the wastes on the sewage treatment process before establishing policies and regulations.

Relatively unpolluted industrial waters should be discharged directly to storm drains because the size of a sewage plant is largely determined by the volume of waste

received. Excessive suspended matter should be removed by pretreatment. Greases, tars and oils also should be recovered to avoid fire hazard and disturbance to sludge digestion.

Various colloidal and soluble organic matter of high B.O.D., especially dairy, brewery, cannery, textile and laundry waste waters, impose a heavy burden on sewage plants; where practicable they should receive preliminary treatment before discharge. Certain solvents (alcohols, acetone, light oils, etc.) may disrupt biological processes. Cyanides, phenols, copper and chromium are toxic to sewage organisms in relatively low concentrations.

Unanticipated changes in industrial operations may cause serious difficulties at sewage plants. Industrial waste should not be condemned indiscriminately, but should be considered in relation to dilution and the general character of the other wastes with which it will be treated.

RICHARD D. HOAK

# Author Index

## Sewage Works Journal, Volume XVIII, 1946


**Allen, Wm. A.** Annual Report for the Year 1944–45 of the Tri-City Sewage Treatment Plant, Pasadena, California ..... 554
ANDERSON, BERTIL G. Toxicity Thresholds of Various Sodium Salts Determined by the Use of *Daphnia Magna* ..... 82
ANDERSON, NORVAL E. See Camp, Thomas R.
ANDERSON, V. Maintenance Problems in a Large Sewage Treatment Plant ..... 536

**Babbitt, H. E.** See Lee, Ming.
BACKMEYER, DAVID. Fourth Operation Report on the Sewage Treatment and Garbage Disposal Plant of Marion, Indiana, for the Year 1944 ..... 317
Pilot Plant Digestion Experiments. (Abs.) ..... 783
Three Industrial Waste Problems at Marion, Indiana. (Abs.) ..... 581
BAXTER, R. R. Sodium Cyanide Waste Kills Fish in White River. (Abs.) ..... 585
BENDER, D. O. Indianapolis Industrial Waste. (Abs.) ..... 586
BERRY, A. E. Development in the Treatment of Sewage and Allied Wastes. (Abs.) ..... 766
BLOODGOOD, DON E. Sewage Treatment and Industrial Wastes. (Abs.) ..... 762
BORUFF, C. S. AND WEINER, L. P. Food By-Products from Grain Alcohol and Whiskey Stillage. (Abs.) ..... 762
BOSE, P. C. Fuel Fertilizer and Calcutta Sewage Sludge. (Abs.) ..... 575
BOULD, C. Preparation and Nature of Town's Refuse-Sewage Sludge Composts. (Abs.) ..... 1251
BOWLUS, F. D. See Pomeroy, Richard.
BRADNEY, LELAND. See Sawyer, Clair N.
BRAGSTAD, R. E. Industrial Wastes at Sioux Falls, South Dakota. (Abs.) ..... 759
BREWER, ROBERT. See Tyler, R. G.
BROOKS, JOHN H., JR. Annual Report for the Year 1944 of the Bureau of Sewers of the City of Worcester, Mass. ..... 1210
BROTHERS, WILLIAM C. Experiments with DDT in Filter Fly Control ..... 181
BROWN, WALTER H. See McNamee, Paul D.
BRUNNER, PAUL L. Couple of Industrial Waste Problems at Fort Wayne. (Abs.) ..... 586
BURDOIN, ALLEN J. Gas Engine Power for Sewage Treatment Plants. (Abs.) ..... 1240
BURRELL, ROBERT. Use of Effluent Water in Sewage Treatment Plants ..... 104

**Caldwell, D. H.** Sewage Oxidation Ponds—Performance, Operation and Design ..... 433
California Sewage Works Association Industrial Wastes Committee of 1945. Report of Procedure for the Handling of Industrial Wastes ..... 503
CALVERT, J. T. See Mills, E. V.
CAMP, THOMAS R. Design of Sewers to Facilitate Flow ..... 5
Sedimentation and Design of Settling Tanks. Discussions, by Norval E. Anderson, R. A. Mulholland, P. Charles Stein, Lynn Perry, E. Sherman Chase and Rolf Eliassen. (Abs.) 1236
CAROLLO, JOHN A. Control of Trickling Filter Flies with DDT ..... 208
CHARLIN, C. A. AND REGAN, C. J. Investigation of Plant Growth Substances (Auxins) in Sewage Products. (Abs.) 1254
CHASE, E. SHERMAN. See Camp, Thomas R.
CHIQUITO, LUCIO. Sanitary Engineering in the Republic of Colombia. (Abs.) ..... 775
CHUBB, ROBERT S. AND MERKEL, PAUL P. Effect of Acid Wastes on Natural Purification of the Schuylkill River ..... 692
CLARK, ROBERT N. The Transmission of Disease by Sewage ..... 1138
COHN, MORRIS M. Effect of Food Wastes on Sewers and Sewage Treatment ..... 477
I Knew Arthur Bedell ..... 1230
COLLIER, JAMES R. Acid Iron Wastes and Diffuser Clogging at Elyria, Ohio ..... 528
COOPER, A. B. Rangoon's Water Supply Back to Normal. (Abs.) ..... 769
Sewerage Problem in Liberated Rangoon. (Abs.) ..... 769
COOPER, G. H. See Mills, E. V.
CRAEMER, GEORGE H. Report on Operation of the Hartford, Conn., Metropolitan District Sewage Treatment Plant for the Years 1943 and 1944 ..... 737

**Darby, W. A.** Operation of Mechanical Screens, Grit Chambers and Clarifiers ..... 289
DARVALL, A. W. See Young, R. S.
DECHER, EDWARD P. Annual Report on the Operation of the Joint Meeting Sewage Treatment Plant in Elizabeth, New Jersey, for the Year Ending 1944 ..... 743
See Rudolfs, Willem.
DILLER, WALTER W. See Hatfield, W. D.
DOUDOROFF, PETER. See Hart, W. B.
DREIER, D. E. Summary of Experience in the Operation of Standard Trickling Filters ..... 704

**Eliassen, Rolf.** See Camp, Thomas R.
ELLIS, M. M. Industrial Wastes and Fish Life. (Abs.) ..... 764
ELLMS, J. W. Report on the Administration, Operation and Maintenance of the Division of Sewage Disposal, Department of Public Utilities, Cleveland, Ohio, for the Year 1943 ..... 113

ESCRITT, L. B. Efficient Detritus Settlement at Comparatively Small Sewage Treatment Works. (Abs.) ..... 349
Research Relating to Sedimentation. (Abs.) ..... 773
Sludge Treatment at Small Sewage Works. (Abs.) ..... 164
EVANS, C. A. AND OSTERUD, K. L. Failure of Poliomyelitis Virus to Grow in Certain Protozoa of Sewage. (Abs.) ..... 1253

**Faber, Harry A.** Sewage Chlorination Reasons and Results ..... 292
FISHBECK, KENNETH. The Design and Operation of Sewage Regulators ..... 651
FLOWER, G. E. Air Diffusion Problems at Cleveland's Southerly Plant ..... 533
Operation and Maintenance of the Southerly Sewage Treatment Plant ..... 119
FORTON, GERALD. Digester Gas Explosion at Traverse City, Michigan ..... 733
FRASCHINA, K. See McNamee, Paul D.
FUHRMAN, RALPH E. Report of Operation of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1945 ..... 1206

**Garner, J. H.** Effect of Mining (Coal) Subsidence on Sewers and Sewage Disposal Works in the West Riding of Yorkshire. (Abs.) ..... 1249
GARRITY, L. V. Sludge Disposal Practices at Detroit. A Discussion ..... 215
GENTER, A. L. Computing Coagulant Requirements in Sludge Conditioning. (Abs.) ..... 589
Sludge Disposal Practices at Detroit. A Discussion ..... 695
Small Sludge Elutriation Plants ..... 26
GERDEL, WALTER E. Digestion Tank Scum ..... 543
Report of the Operation and Maintenance of the Westerly Sewage Treatment Plant ..... 117
GOLDTHORPE, H. H. The Treatment of Textile Wastes at Huddersfield, (England). (Abs.) ..... 765
GREENBANK, JOHN. See Hart, W. B.
GREENE, R. A. Sludge Disposal Practices at Detroit. A Discussion ..... 219
GRINDLEY, J. Treatment and Disposal of Waste Waters Containing Chromate. (Abs.) ..... 1244
GUNSON, C. P. Prearerated Raw Sludge Recirculation Increases Primary Sedimentation Efficiency at Denver. 1121

**Hall, A. J.** See Young, R. S.
HALPERIN, ZE'EN. Tartrates Recovered from Winery Wastes. (Abs.) ..... 169
HART, W. B. Disposal of Petroleum Refinery Wastes. (Abs.) ..... 1245
HART, W. B., DOUDOROFF, PETER AND GREENBANK, JOHN. Evaluation of the Toxicity of Industrial Wastes, Chemicals and Other Substances to Fresh-Water Fishes. (Abs.) ..... 350
HATFIELD, W. D. AND DILLER, WALTER W. The Determination of Suspended Solids in Sewage. A Discussion ..... 230
HAVENS, WILLIAM L. AND JONES, FRANK WOODBURY. Getting the Most Out of Sewage Works Data. (Abs.) ..... 162
HAY, THOMAS T. Experience in Grit Removal and Handling at Racine, Wis. 54
HEIDER, ROBERT W. Cannery Waste Treatment. (Abs.) ..... 170, 588
Stream Pollution in the Blue River Basin. (Abs.) ..... 170
Stream Pollution in the Marimee River Basin. (Abs.) ..... 169
Stream Pollution in the Muscatatuck River Basin. (Abs.) ..... 171
Stream Pollution in the Patoka River Basin. (Abs.) ..... 589
Stream Pollution in the Whitewater River Basin. (Abs.) ..... 170
HERDA, N. Report of Operation of the Willow Run Bomber Plant, Detroit, Michigan, Sewage Treatment Plant for the Years 1943 and 1944 ..... 1205
Treatment of Cyanide and Acid Plating Wastes ..... 499
HILL, KENNETH V. Modern Design Trends for Sewage Treatment. (Abs.) 1254
HOAK, RICHARD D. Rational Examination of Stream Pollution Abatement. (Abs.) ..... 166
HOLDERBY, J. M. Trickling Filter Treatment of Sulfite Waste Liquor ..... 671
HOLLOWELL, ROBERT, JR. History and Legal Background of Stream Pollution Control in Indiana. (Abs.) ..... 760
HOLMES, PAUL M. Intermittent Sand Filter Found Useful in Rural Sanitation. (Abs.) ..... 350
HOOD, JOHN W. Fundamentals of Biological Oxidation-Clarification ..... 656
HUBBELL, CLARENCE W. Sludge Disposal Practices at Detroit ..... 212
HUFF, J. E. Items to Consider When Planning Sewage Plant Extensions or Improvements. (Abs.) ..... 784
Wooden Mill Waste at LaPorte Sewage Treatment Plant. (Abs.) ..... 585
HURLEY, JOHN. A National Policy for Trade Effluents. (Abs.) ..... 769
Are We Backward in Sewage Disposal. (Abs.) ..... 771
Presidential Address, Institute of Sewage Purification (1945) (Abs.) ..... 769

**Imhoff, Karl.** Digester Gas for Automobiles ..... 17

**Jennings, Arthur J.** Digester Gas Explosion at Monroe, Mich. ..... 529
JUDSON, C. See Wishart, J. M.
JOHNSON, HERBERT O. Small Plant Operation ..... 1191
See Riddick, Thomas M.
JONES, FRANK WOODBURY. Trickling Filter and Its Operation ..... 89
See Havens, William L.

**Kappe, Stanley E.** Operation and Maintenance of Mechanical Equipment ..... 297
KENNISON, KARL R. Disposal Plant to Alleviate Boston Harbor Nuisance. (Abs.) ..... 1241
KLEIN, L. See Wishart, J. M.
KLEVEN, J. B. Clarifiers. (Abs.) ..... 784
KOCH, WILMER, H. Facts About Chlorine 1194
KRAUS, L. S. Digested Sludge—An Aid to the Activated Sludge Process ..... 1099

**Lea, W. S.** Sewage Pumping Stations... 238
LeBosquet, M., Jr. See Ruchhoft, C. C.
Lee, Ming and Babbitt, H. E. Constant Velocity Grit Chamber with Parshall Flume Control ... 646
Liebowitz, A. See Young, R. S.
Little, N. Campbell. Some Aspects Concerning the Sewage of Rural Areas. (Abs.) ... 767
Lovell, T. R. Operations Report for the Fiscal Year 1944-45 on the Sewage Treatment Plant of the City of Marshalltown, Iowa ... 548
Lovett, M. Sewerage and Sewage Disposal in Retrospect and Prospect. (Abs.) ... 576
Lunt, Herbert A. Preliminary Greenhouse Studies of Digested Sludge as a Fertilizer ... 46

**Mann, Uhl T.** Plain Aeration of Sewage 459
Manning, Humphrey D. Postwar Application of Wartime Experience in Sewage Disposal. (Abs.) ... 163
Manteufel, L. Fourth Annual Report of the Sewage Incinerator Committee, Wausau, Wisconsin. (Abs.) ... 780
Martin, George. Thirteenth Annual Report of the Green Bay, Wisconsin, Metropolitan Sewerage District Commission for the Year Ending March 31, 1945 ... 1208
Maske, William. See Tyler, R. G.
Mathews, W. W. Bark From the Daily Log ... 1198
Fourth Annual Report on the Gary, Indiana, Sewage Treatment Works for 1944 ... 325
McKee, J. E. Monsieur le Vidangeur ... 534
McLean, D. L. Summary of Plant Operations for the Year 1944 of the Greater Winnipeg Sanitary District, Winnipeg, Manitoba ... 1202
McNamee, Paul D., Fraschina, K., and Brown, Walter H. Computing Coagulant Requirements in Sludge Conditioning. A Discussion. (Abs.) 1238
Meckler, Wm. G. See Ruchhoft, C. C.
Merkel, Paul P. See Chubb, Robert S.
Merryfield, Fred and Wilmot, W. G. 1945 Progress Report on Pollution of Oregon Streams. (Abs.) ... 780
Merz, R. C. Grit Collection and Conditioning ... 481
Metcalf and Eddy. Report to Honolulu Sewerage Committee Upon Sewerage and Sewage Disposal. (Abs.) ... 772
Millar, J. N. See Rudolfs, Willem.
Milling, Martin A. Industrial Waste Treatment. (Abs.) ... 584
Mills, E. V. Treatment of Settled Sewage by Continuous Filtration with Recirculation of Part of the Effluent. (Abs.) ... 776
Treatment of Settled Sewage in Percolating Filters in Series with Periodic Change in the Order of the Filters. (Abs.) ... 777
Mills, E. V., Calvert, J. T. and Cooper, G. H. Treatment of Camp Sewage and Laundry Waste Water by Alternating Double Filtration. (Abs.) ... 348
Mohlman, F. W. Utilization and Disposal of Industrial Wastes. (Abs.) ... 760
Morgan, L. S. Sewage Plant Records and Operation Reports ... 92
Mulholland, R. A. See Camp, Thomas R.
Murdock, Harold R. Current Developments in Waste Utilization. (Abs.) ... 345, 582, 1256

**National Research Council.** Sewage Treatment at Military Installations. 787
Niles, A. H. Thirteenth Annual Report of the Division of Sewage Disposal of the City of Toledo, Ohio, for the Year 1944 ... 555

**Oeming, Loring F.** Industrial Waste Treatment and Control. (Abs.) ... 343
Stream Pollution Problems of the Electroplating Industry ... 678
Oke, E. E. W. Increased Efficiency from an Old Sewage Disposal Plant. (Abs.) 581
Oliver, F. Wartime Treatment of Sewage and Sludge Disposal. (Abs.) ... 1244
Oliver, W. Darlington Sewage Works and Farm. (Abs.) ... 165
Osterud, K. L. See Evans, C. A.

**Palmer, Clyde L.** Control of Sewer Usage at Detroit, Michigan ... 1127
Parker, C. D. The Corrosion of Concrete, I. The Isolation of a Species of Bacterium Associated with the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide. (Abs.) ... 172
*Ibid.* II. The Function of *Thiobacillus Concretivorus* (Nov. Spec.) in the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide. (Abs.) ... 173
Parker, W. The Propulsion of Vehicles by Compressed Gas. (Abs.) ... 770
Pence, Irel V. Cannery Waste Problems at the Peru, Indiana, Sewage Treatment Plant. (Abs.) ... 585
Perry, Lynn. See Camp, Thomas R.
Placak, O. R. and Ruchhoft, C. C. A Study of Wastes From the Synthetic Rubber Industry ... 1169
Pomeroy, Richard and Bowlus, F. D. Los Angeles County Sanitation District Sulfide Control Report ... 597
Prescott, S. C. Water Bacteriology ... 785

**Quinn, Joseph L., Jr.** Industrial Wastes and Stream Pollution. (Abs.) ... 764

**Regan, C. J.** See Chaplin, C. A.
Riddick, Thomas M. and Johnson, Herbert O. Solids Removal as Influenced by Plant Design ... 419
Ridenour, G. M. Some Fundamental Concepts in Expression of Loadings and Efficiencies ... 641
Riley, K. W. Grand Forks Water and Sewage. (Abs.) ... 1254
Rooke, C. G., Jr. Talco Refinery Trade-Waste Treating Purifies Water for Cooling. (Abs.) ... 582

Ross, W. E. Industrial Waste Problems at Richmond Sewage Treatment Works. (Abs.) ..... 586
Ruchhoft, C. C. See Placak, O. R.
Ruchhoft, C. C., LeBosquet, M., Jr., and Meckler, William G. TNT Wastes From Shell-Loading Plants—Color Reactions and Disposal Procedures. (Abs.) ..... 339
Ruchhoft, C. C. and Meckler, Wm. G. Colored TNT Derivative and Alpha-TNT in Colored Aqueous Alpha-TNT Solutions. (Abs.) ..... 779
Rudgal, H. T. The Effects of Copper-Bearing Wastes on Sludge Digestion 1150
Rudolfs, Willem. By-Products and Treatment of Brewery and Yeast Wastes. (Abs.) ..... 762
Critical Review of the Literature of 1945 on Sewage and Waste Treatment and Stream Pollution ..... 244
Effects of Ground Garbage on Sewage Treatment Processes ..... 1141
Rudolfs, Willem and Dechter, Edward P. Operation Efficiency and Factors Affecting Operation at the Elizabeth Joint Meeting Plant ..... 66
Rudolfs, Willem and Millar, J. N. A Method for Accelerated Equalization of Industrial Wastes ..... 686

**Salt, Norman.** Practical Aspects of Sludge Treatment at the Yardley Works of the Birmingham Tame and Rea District Drainage Board. (Abs.) 1242
Samson, Channel. Progressive Development of District 2 Sewage Works, Tonawanda, N. Y. ..... 103
Sanborn, N. H. Food Canning Waste Utilization. (Abs.) ..... 763
Sawyer, Clair N. and Bradney, Leland. Modernization of the B.O.D. Test for Determining the Efficacy of Sewage Treatment Processes ..... 1143
Schroepfer, George J. See Velzy, C. R.
Scott, G. R. Stream Sanitation ..... 281
Setter, L. R. Plain Aeration of Sewage. A Discussion ..... 171
Shephard, W. F. Certification of Sewage Treatment Plant Operators ..... 231
Siebert, Christian L. Effect of Industrial Wastes on Sewage Treatment ..... 97
Simpson, R. W. Ingenuity Tool of the Operator ..... 1182
Smith, Edward J. Incineration of Fine Screenings at Niagara Falls, N. Y. ..... 221
Southgate, B. A. Treatment and Disposal of Waste Waters from Paper Mills. (Abs.) ..... 340
Work of the Water Pollution Research Laboratory During the War. (Abs.) ..... 578
Sperry, Walter A. Bark From the Daily Log ..... 109, 312, 539, 729
Fourteenth Annual Report on the Aurora, Illinois, Sanitary District Sewage Treatment Plant for the Year 1944 ..... 742
Stein, P. Charles. See Camp, Thomas R.
Szymanski, John R. Annual Report for the Year Ending March 31, 1945, of the Sewage Disposal Commission of New Britain, Conn. ..... 741

**Temple, F. C.** Public Health In India. (Abs.) ..... 768
Tomlinson, T. G. Control by DDT of Flies Breeding in Percolating Sewage Filters. (Abs.) ..... 1253
Tuemler, H. A. Waste Saving by Improvements in Milk Plant Equipment. (Abs.) ..... 759
Tucker, Belden S. Army Sewerage on Hawaii. (Abs.) ..... 162
Tyler, R. G., Maske, William and Brewer, Robert. Treatment of Sulfite Waste Liquor on High Rate Trickling Filters ..... 1155

**Van Kleeck, LeRoy W.** Operation of Connecticut's Sewage Treatment Plants. (Abs.) ..... 171
Velzy, C. R. Concentration of Sewage Sludge, A Discussion. (Abs.) ..... 1240
Velzy, C. R. and Schroepfer, George J. Dewatering, Incineration and Use of Sewage Sludge. (Abs.) ..... 1238
Viehl, Karl. Purification of Domestic Sewage by Digestion. (Abs.) ..... 165

**Warrick, L. F.** Wisconsin Progress Report on Sanitary Engineering and Stream Pollution Control Activities, 1942 1943. (Abs.) ..... 783
Watson, W. Controlled Septicity of Sewage. (Abs.) ..... 577
Weiner, L. P. See Boruff, C. S.
Weston, Roy F. The Waste Disposal and Utilization Problems of the Petroleum Industry. (Abs.) ..... 763
White, Paul W. Industrial Waste Problems at Muncie Sewage Plant. (Abs.) 586
Wilmot, W. G. See Merryfield, Fred.
Wirts, John J. Report on the Operation and Maintenance of the Easterly Sewage Treatment Plant ..... 111
Wise, William S. Treatment of Wastes Produced in Metallurgical and Metal Working Industries. (Abs.) ..... 761
Wisely, W. H. National Stream Pollution Control Activities. (Abs.) ..... 587
Wishart, J. M., Jepson, C. and Kelly, L. Dewatering of Sewage Sludge by Coagulation and Vacuum Filtration, Part I, Laboratory Experiments. (Abs.) ..... 765
Witcher, C. Preston. Annual Report for the Years 1942–43–44 on the Operation of the Ann Arbor, Michigan, Sewage Treatment Plant ..... 552

**Young, R. S., Hall, A. J. and Darvall, A. W.** Sewage Treatment at an African Native Community ..... 1151
Young, R. S. and Liebowitz, A. Determination of Suspended Solids in Sewage ..... 228

# Subject Index

## Sewage Works Journal, Volume XVIII, 1946


**Accounting** (See Administration)

ACTIVATED SLUDGE

Digested Sludge—An Aid to the Activated Sludge Process, *L. S. Kraus* ... 1099
Sewage Treatment at Military Installations, *National Research Council* ... 787

ADMINISTRATION

Civic Leadership and Public Relations ... 527
Constructive Publicity in Public Relations ... 288
Control of Sewer Usage at Detroit, Michigan, *Clyde L. Palmer* ... 1127
Getting the Most Out of Sewage Works Data, *William L. Havens* and *Frank Woodbury Jones*, (Abs.) ... 162
Personal Courtesy and Public Relations ... 88
Sewage Plant Records and Operating Records, *L. S. Morgan* ... 92
Sewage Treatment at Military Installations, *National Research Council* ... 787

AERATION

Acid Iron Wastes and Diffuser Clogging at Elyria, Ohio, *James R. Collier* ... 528
Air Diffusion Problems at Cleveland's Southerly Plant, *G. E. Flower* ... 533
Plain Aeration of Sewage, *Ethel T. Mann* ... 459
Plain Aeration of Sewage, A Discussion, *L. R. Setter* ... 471

ANALYTICAL METHODS

Determination of Suspended Solids in Sewage, *R. S. Young* and *A. Liebowitz* ... 228
Determination of Suspended Solids in Sewage, A Discussion, *W. D. Hatfield* and *Walter W. Diller* ... 230
Modernization of the B.O.D. Test for Determining the Efficacy of Sewage Treatment Processes, *Clair N. Sawyer* and *Leland Bradney* ... 1113
Water Bacteriology, *S. C. Prescott* ... 785

**Biology**

Corrosion of Concrete. I. The Isolation of a Species of Bacterium Associated with the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide, *C. D. Parker*, (Abs.) ... 172
Corrosion of Concrete. II. The Function of *Thiobacillus Concretivorus* (Nov. Spec.) in the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide, *C. D. Parker*, (Abs.) ... 173
Evaluation of the Toxicity of Industrial Wastes, Chemicals and Other Substances to Fresh-Water Fishes, *W. Bregy Hart, Peter Doudoroff* and *John Greenbank*, (Abs.) ... 350
Failure of Poliomyelitis to Grow in Certain Protozoa of Sewage, *C. A. Evans* and *K. L. Osterud*, (Abs.) ... 1253
Transmission of Disease by Sewage, *R. N. Clark* ... 1138
Water Bacteriology, *S. C. Prescott* ... 785

BOOK REVIEWS

Water Bacteriology, *S. C. Prescott* ... 785

**Character of Sewage**

Sewage Treatment at Military Installations, *National Research Council* ... 787
Transmission of Disease by Sewage, *R. N. Clark* ... 1138

CHEMICAL TREATMENT

Fundamentals of Biological Oxidation-Clarification, *John W. Hart* ... 656

CHEMISTRY (See Analytical Methods)

CHLORINATION

Facts About Chlorine, *Widmer H. Koch* ... 1194
Sewage Chlorination Research and Results, *Harry A. Faber* ... 202

CLARIFICATION (See Sedimentation)

COMMINUTION (See Screening)

CONCENTRATION (See Sludge Concentration)

CONSTRUCTION

Public Construction in Perspective ... 562

CONTACT AERATION

Sewage Treatment at Military Installations, *National Research Council* ... 787

CORROSION

Los Angeles County Sanitation District Sulfide Control Report, *Richard Pomeroy* and *F. D. Bufalus* ... 597

**Daily Log**

Bark From the Daily Log, *W. W. Mathews* ... 1198
Bark From the Daily Log, *W. A. Sperry* ... 109, 312, 539, 729

DESIGN

Sewage Oxidation Ponds—Performance, Operation and Design, *D. H. Caldwell* ... 433

Sewerage and Sewage Disposal in Retrospect and Prospect. *M. Lovett.* (Abs.) ..... 576

DIGESTION (See Sludge Digestion)

DIRECTORY (See Federation Affairs)

**Editorials**

Civic Leadership and Public Relations ..... 527
Constructive Publicity in Public Relations ..... 288
Federal Anti-Pollution Legislation Progresses ..... 702
Federal Policy on Public Works ..... 331
Filter Fly Control by DDT ..... 330
Industrial Wastes Activity in the Federation ..... 1217
It Will Be the Nineteenth Annual Meeting at Toronto ..... 127
Modernized Format ..... 126
No Slimes—No Sulfides—No Odors ..... 703
NRC Report ..... 1029
Personal Courtesy and Public Relations ..... 88
Public Construction in Perspective ..... 562
Twentieth Annual Meeting in 1947 to be Concurrent with AWWA Conference at San Francisco ..... 1030
View or Two on Domestic Garbage Grinders ..... 751
What Every Citizen Should See ..... 1182

EFFLUENT UTILIZATION

Darlington Sewage Works and Farm. *W. Oliver* ..... 165
Esso Refinery Trade-Waste Treating Purifies Water for Cooling. *C. G. Rook, Jr.* ..... 582
Use of Effluent Water in Sewage Treatment Plants. *Robert Borrell* ..... 104

ELUTRIATION (See Sludge Elutriation)

EQUIPMENT AND SUPPLIES

American Brass Company ..... 1037
American Car and Foundry ..... 1038
American Concrete Pipe Company ..... 1039
Builders Providence ..... 1041
Carborundum Company ..... 1043
Cast Iron Pipe Research Association ..... 1044
Chain Belt Company ..... 1045
Chicago Pump Company ..... 1047
Clay Products Association ..... 1049
Dorr Company ..... 1050
Gale Oil Separator Company ..... 1051
Gruendler Crusher and Pulverizer Company ..... 1052
Hardinge Company ..... 1053
Hersey Manufacturing Company ..... 1055
Infilco, Inc. ..... 1057
Innis, Speiden and Company ..... 1059
Johns Manville ..... 1061
Komline Sanderson Engineering Corporation ..... 1062
Lakeside Engineering Corporation ..... 1064
LaMotte Chemical Products Company ..... 1066
Link Belt Company ..... 1067
Magnetite Filter Company ..... 1069
Mine Safety Appliances Company ..... 1070
Nichols Engineering and Research Corporation ..... 1072
Nordstrom Valve Company ..... 1073
Pacific Flush Tank Company ..... 1075
Pittsburgh Equitable Meter Company ..... 1078
Roots Connersville Blower Corporation ..... 1079
Royer Foundry and Machine Company ..... 1081
Simplex Valve and Meter Company ..... 1083
Tennessee Corporation ..... 1085
U. S. Pipe and Foundry Company ..... 1087
Vapor Recovery Systems Company ..... 1088
Walker Process Equipment Company ..... 1090
Wallace and Tiernan Company ..... 1092
Yeomans Brothers Company ..... 1093

EXPLOSIONS (See Safety)

**Federation Affairs**

Arthur S. Bedell (1887-1946) ..... 573
Canada Beckons in October ..... 573
Critical Review of the Literature of 1945 on Sewage and Waste Treatment and Stream Pollution. *Willem Rudolfs, et al* ..... 241
Directory of Members ..... 353
Dr. Rudolfs Elected to Honorary Membership ..... 159
I Knew Arthur Bedell. *Morris M. Cohn* ..... 1231
Minutes of Meeting of 1945 Board of Control ..... 131
Minutes of Meeting of 1945 Election Committee ..... 137
Minutes of Meeting of 1946 Board of Control ..... 138
1945 Membership Prizes to Canadian and Arizona Associations ..... 160
Nineteenth Annual Meeting a Great Success ..... 1232
Nineteenth Annual Meeting Takes Shape ..... 758
Preview of the Nineteenth Annual Meeting ..... 1031
Qualifications of Sewage Treatment Plant Operators ..... 147
Report of Committee on Awards ..... 159
Report of Committee on Operation Reports ..... 157
Report of Executive Secretary-Editor ..... 144
Report of Sewage Works Practice Committee ..... 155
Rules for 1946 Membership Contest ..... 160
Surplus Property Purchase Procedure ..... 574

FERTILIZER (See Sludge Utilization)

FINAL SEDIMENTATION (See Sedimentation)

**Gadgets**

Ingenuity—Tool of the Operator. *R. W. Simpson* ..... 1182

GARBAGE DISPOSAL WITH SEWAGE

Effect of Food Wastes on Sewers and Sewage Treatment. *Morris M. Cohn* ..... 477
Effects of Ground Garbage on Sewage Treatment Processes. *Willem Rudolfs* ..... 1144
View or Two on Domestic Garbage Grinders ..... 751

GAS (See Sludge Gas Utilization)

GREASE REMOVAL AND DISPOSAL
Grit Collection and Conditioning. *R. C. Merz* ... 484

GRIT REMOVAL AND CONDITIONING
Constant Velocity Grit Chamber with Parshall Flume Control. *Ming Lee* and *H. E. Babbitt* ... 646
Efficient Detritus Settlement at Comparatively Small Sewage Treatment Works. *L. B. Escritt.* (Abs.) ... 349
Experience in Grit Removal and Handling at Racine, Wisconsin. *Thomas T. Hay* ... 54
Operation of Mechanical Screens, Grit Chambers and Clarifiers. *W. A. Darby* ... 289
Sewage Treatment at Military Installations. *National Research Council* ... 787

**High Rate Filters** (See Trickling Filters)

**Incineration** (See Screenings Disposal or Sludge Incineration)

INDUSTRIAL WASTES
BREWERY
By-Products and Treatment of Brewery and Yeast Wastes. *William Rudolfs.* (Abs.) ... 762
CANNERY
Cannery Waste Problems at the Peru, Indiana, Sewage Treatment Plant. *Irel V. Pence.* (Abs.) ... 585
Cannery Waste Treatment. *Robert W. Heider.* (Abs.) ... 170, 588
Food Canning Waste Utilization. *N. H. Sanborn.* (Abs.) ... 763
DISTILLERY
Feed By-Products from Grain Alcohol and Whiskey Stillage. *C. S. Boruff* and *L. P. Werner.* (Abs.) ... 762
EXPLOSIVES MANUFACTURE
Colored TNT Derivative and Alpha-TNT in Colored Aqueous Alpha-TNT Solutions. *C. C. Ruchhoft* and *Wm. G. Meckler.* (Abs.) ... 779
TNT Wastes from Shell-Loading Plants Color Reactions and Disposal Procedures. *C. C. Ruchhoft, M. LeBosquet, Jr.* and *Wm. G. Meckler.* (Abs.) ... 339
GAS PLANT
Indianapolis Industrial Waste. *D. O. Bender.* (Abs.) ... 586
GENERAL
Current Developments in Waste Utilization. *Harold R. Murdock.* (Abs.) ... 345, 582, 1256
Development in the Treatment of Sewage and Allied Wastes. *A. E. Berry.* (Abs.) ... 766
Effect of Acid Wastes on Natural Purification of the Schuylkill River. *Robert S. Chabb* and *Paul P. Merkel* ... 692
Effect of Industrial Wastes on Sewage Treatment. *Christian L. Siebert* ... 97
Evaluation of the Toxicity of Industrial Wastes, Chemicals and Other Substances to Fresh-Water Fishes. *W. Bregy Hart, Peter Doudoroff* and *John Greenbank.* (Abs.) ... 350
Industrial Waste—An Important Factor in Process Planning. (Abs.) ... 168
Industrial Wastes Activity in the Federation ... 1217
Industrial Wastes and Fish Life. *M. M. Ellis.* (Abs.) ... 764
Industrial Wastes and Stream Pollution. *Joseph L. Quinn, Jr.* (Abs.) ... 764
Industrial Waste Treatment. *Martin A. Milling.* (Abs.) ... 584
Industrial Waste Treatment and Control. *L. F. Oeming.* (Abs.) ... 343
Method for Accelerated Equalization of Industrial Wastes. *William Rudolfs* and *J. N. Millar* ... 686
National Policy for Trade Effluents. *John Hurley.* (Abs.) ... 769
Report of Procedure for the Handling of Industrial Wastes. *California Sewage Works Association Industrial Wastes Committee of 1945* ... 503
Sewage Treatment and Industrial Wastes. *Don E. Bloodgood.* (Abs.) ... 762
Three Industrial Waste Problems at Marion, Indiana. *David Backmeyer.* (Abs.) ... 584
Toxicity Thresholds of Various Sodium Salts Determined by the Use of *Daphnia Magna*. *Bertil G. Anderson* ... 82
Utilization and Disposal of Industrial Wastes. *F. W. Mohlman.* (Abs.) ... 760
METAL PROCESSING
Acid Iron Wastes and Diffuser Clogging at Elyria, Ohio. *James R. Collier* ... 528
Couple of Industrial Waste Problems at Fort Wayne. *Paul L. Brunner.* (Abs.) ... 586
Effects of Copper-Bearing Wastes on Sludge Digestion. *H. T. Rudgal* ... 1130
Industrial Waste Problems at Muncie Sewage Plant. *Paul W. White.* (Abs.) ... 586
Industrial Waste Problems at Richmond Sewage Treatment Works. *W. E. Ross.* (Abs.) ... 586
Industrial Waste Problem to be Solved. (Abs.) ... 1250
Sodium Cyanide Waste Kills Fish in White River. *R. R. Baxter.* (Abs.) ... 585
Stream Pollution Problems of the Electroplating Industry. *L. F. Oeming* ... 678
Treatment and Disposal of Waste Waters Containing Chromate. *J. Grindley.* (Abs.) ... 1244
Treatment of Cyanide and Acid Plating Wastes. *Nicholas Herda* ... 499
Treatment of Wastes Produced in Metallurgical and Metal Working Industries. *William S. Wise.* (Abs.) ... 761
MILK PROCESSING
Waste Saving by Improvements in Milk Plant Equipment. *H. A. Trebler.* (Abs.) ... 759

PACKINGHOUSE
Industrial Wastes at Sioux Falls, South Dakota. *R. E. Bragstad.* (Abs.) 759

PAPER MANUFACTURE
Butyl Alcohol by Fermentation of Waste Sulfite Liquor. (Abs.) 168
Treatment and Disposal of Waste Waters from Paper Mills. *B. A. Southgate.* (Abs.) 340
Treatment of Sulfite Waste Liquor on High Rate Trickling Filters. *R. G. Tyler, William Maske* and *Robert Brewer* 1155
Trickling Filter Treatment of Sulfite Waste Liquor. *J. M. Holdcroft* 671

PETROLEUM
Disposal of Petroleum Refinery Wastes. *W. B. Hart.* (Abs.) 1245
Talco Refinery Trade-Waste Treating Purifies Water for Cooling. *C. G. Rook, Jr.* (Abs.) 582
Waste Disposal and Utilization Problems of the Petroleum Industry. *Roy F. Weston.* (Abs.) 763

RUBBER MANUFACTURE
Study of Wastes From the Synthetic Rubber Industry. *O. R. Placak* and *C. C. Ruchhoft* 1169

TEXTILE
Treatment of Textile Wastes at Huddersfield (England). *H. H. Goldthorpe.* (Abs.) 765
Woolen Mill Waste at LaPorte Sewage Treatment Plant. *John E. Happ.* (Abs.) 585

WINERY
Tartrates Recovered From Winery Wastes. *Le'on Halperin.* (Abs.) 169

INTERMITTENT SAND FILTERS
Intermittent Sand Filter Found Useful in Rural Sanitation. *Earl M. Holmes.* (Abs.) 350

IRRIGATION (See Effluent Utilization)

**Laws** (See Administration of Stream Pollution)

LICENSING OF OPERATORS
Certification of Sewage Treatment Plant Operators. *W. F. Shephard* 231

LITIGATION
People of the State of California, Plaintiff v. City of Los Angeles et al Defendants. (Abs.) 781

**Maintenance and Repair**
Maintenance Problems in a Large Sewage Treatment Plant. *Virgil Anderson* 536
Operation and Maintenance of Mechanical Equipment. *Stanley E. Kappe* 297
Rangoon's Water Supply Back to Normal. *A. B. Cooper.* (Abs.) 769
Sewerage Problem in Liberated Rangoon. *A. B. Cooper.* (Abs.) 769

MEMBER ASSOCIATIONS (See Proceedings of Member Associations)

**Odor Control**
Los Angeles County Sanitation District Sulfide Control Report. *Richard Pomeroy* and *F. D. Bodtius* 597
No Slimes—No Sulfides—No Odors 703

OPERATION OF PLANTS
Annual Report for the Year Ending March 31, 1945, of the Sewage Disposal Commission of New Britain, Conn. *John R. Szymanski* 741
Annual Report for the Year 1944 of the Bureau of Sewers of the City of Worcester, Mass. *John H. Brooks, Jr.* 1210
Annual Report for the Year 1944–45 of the Tri-City Sewage Treatment Plant, Pasadena, California. *William A. Allen* 554
Annual Report of the Buffalo Sewer Authority for 1943–1944 319
Annual Report on the Operation of the Joint Meeting Sewage Treatment Plant in Elizabeth, New Jersey, for the Year Ending 1944. *Edward P. Decher* 743
Army Sewerage in Hawaii. *Belton S. Tucker.* (Abs.) 162
Darlington Sewage Works and Farm. *W. Oliver.* (Abs.) 165
Fourteenth Annual Report on the Aurora, Illinois, Sanitary District Sewage Treatment Plant for the Year 1944. *Walter A. Sperry* 742
Fourth Annual Report of the Sewage Incinerator Committee, Wausau, Wisconsin. *L. Mandeufel.* (Abs.) 780
Fourth Annual Report on the Gary, Indiana, Sewage Treatment Works for 1944. *W. W. Mathews* 325
Fourth Operation Report on Sewage Treatment and Garbage Disposal Plant of Marion, Indiana, for the Year 1944. *David Backmeyer* 317
Grand Forks Water and Sewage. *K. W. Riley.* (Abs.) 1254
Increased Efficiency from an Old Sewage Disposal Plant. *E. E. W. Oke.* (Abs.) 581
Melbourne and Metropolitan Board of Works, Report For Year Ended June 30, 1945. (Abs.) 771
Operation and Maintenance of the Southerly Sewage Treatment Plant. *G. E. Flower* 119
Operation Efficiency and Factors Affecting Operation at the Elizabeth Joint Meeting Plant. *Willem Rudolfs* and *Edward P. Decher* 66
Operation of Connecticut's Sewage Treatment Plants. *LeRoy W. Van Kleeck.* (Abs.) 171
Operations Report for the Fiscal Years 1942–43–44 on the Operation of the Ann Arbor, Michigan, Sewage Treatment Plant. *C. Preston Witcher* 552
Operations Report for the Fiscal Year 1944–45 on the Sewage Treatment Plant of the City of Marshalltown, Iowa. *T. R. Lovell* 548

Post-War Application of Wartime Experience in Sewage Disposal. *Humphrey D. Manning.* (Abs.) 163
Practical Aspects of Sludge Treatment at the Yardley Works of the Birmingham Tame and Rea District Drainage Board. *Norman Salt.* (Abs.) 1242
Progressive Development of District 2 Sewage Works, Tonawanda, N. Y. *Channel Samson* 493
Report on the Operation and Maintenance of the Easterly Sewage Treatment Plant. *John J. Wirts* 111
Report of the Operation and Maintenance of the Westerly Sewage Treatment Plant. *Walter E. Gerdel* 117
Report of Operation of the District of Columbia Sewage Treatment Plant for the Fiscal Year 1945. *Ralph E. Fuhrman* 1206
Report of Operation of the Willow Run Bomber Plant, Detroit, Michigan, Sewage Treatment Plant for the Years 1943 and 1944. *Nicholas Herda* 1205
Report on Operation of the Hartford, Conn., Metropolitan District Sewage Treatment Plant for the Years 1943 and 1944. *George H. Craemer* 737
Report on the Administration, Operation and Maintenance of the Division of Sewage Disposal, Department of Public Utilities, Cleveland, Ohio, for the Year 1943. *J. W. Ellms* 113
Sewage Oxidation Ponds—Performance, Operation and Design. *D. H. Caldwell* 433
Sewage Treatment at an African Native Community. *R. S. Young, A. J. Hall and A. W. Darvall* 1151
Small Plant Operation. *Herbert O. Johnson* 1191
Summary of Plant Operations for the Year 1944 of the Greater Winnipeg Sanitary District, Winnipeg, Manitoba. *D. L. McLean* 1202
Thirteenth Annual Report of the Division of Sewage Disposal of the City of Toledo, Ohio, for the Year 1944. *A. H. Niles* 555
Thirteenth Annual Report of the Green Bay, Wisconsin, Metropolitan Sewerage District Commission for the Year Ending March 31, 1945. *George Martin* 1208

OPERATION REPORTS

Getting the Most Out of Sewage Works Data. *William L. Havens and Frank Woodbury Jones.* (Abs.) 162
Sewage Plant Records and Operating Reports. *L. S. Morgan* 92

OXIDATION PONDS

Sewage Oxidation Ponds—Performance, Operation and Design. *D. H. Caldwell* 433
Sewage Treatment at Military Installations. *National Research Council* 787

**Paints** (See Maintenance and Repair)

PLANNING

Are We Backward in Sewage Disposal? *John Hurley.* (Abs.) 774
Disposal Plant to Alleviate Boston Harbor Nuisance. *Karl R. Kennison.* (Abs.) 1241
Items to Consider When Planning Sewage Plant Extensions or Improvements. *J. E. Hupp.* (Abs.) 784
Modern Design Trends for Sewage Treatment. *Kenneth V. Hill.* (Abs.) 1254
Presidential Address, Institute of Sewage Purification (1945). *John Hurley.* (Abs.) 769
Report to Honolulu Sewerage Committee Upon Sewerage and Sewage Disposal. *Metcalf and Eddy.* (Abs.) 772
Some Aspects Concerning the Sewerage of Rural Areas. *N. Campbell Little.* (Abs.) 767

PREAERATION

Preaerated Raw Sludge Recirculation Increases Primary Sedimentation Efficiency at Denver. *C. P. Gunson* 1121

PROCEEDINGS OF MEMBER ASSOCIATIONS

Arizona Sewage and Water Works Association 570, 753
Arkansas Group Moves to Join Federation 754
Canadian Institute on Sewage and Sanitation 332
Florida Sewage Works Association 1219
Georgia Water and Sewage Association 333
Kansas Water and Sewage Works Association 565
Member Association Meetings 130, 338, 571, 757, 1249
Michigan Sewage Works Association 755
Missouri Water and Sewerage Conference 128
Montana Sewage Works Association 756
New Jersey Sewage Works Association 1220
New Member Association Proposed at Inter-American Sanitary Engineering Conference 1222
New York State Sewage Works Association 567, 1225
North Carolina Sewage Works Association 334
North Dakota Water and Sewage Works Conference 335
Ohio Conference on Sewage Treatment 129, 1226
Oklahoma Water and Sewerage Conference 336
Pacific Northwest Sewage Works Association 1227
South Dakota Water and Sewage Works Conference 337
Texas Water Works and Sewerage Short School and Texas Sewage Works Section 566

PUBLIC HEALTH ASPECTS

Failure of Poliomyelitis Virus to Grow in Certain Protozoa of Sewage. *C. A. Evans and K. L. Osterud.* (Abs.) 1253
Transmission of Disease by Sewage. *R. N. Clark* 1138

PUMPING OF SEWAGE
Sewage Pumping Stations. *W. S. Lea* 239

**References to Sewage Literature** 175, 591

RESEARCH
British Institute Discusses Recent Research 735
Critical Review of the Literature of 1945 on Sewage and Waste Treatment and Stream Pollution. *Willem Rudolfs et al* 244
Fundamentals of Biological Oxidation-Clarification. *John W. Hood* 656
Work of the Water Pollution Research Laboratory During the War. *B. A. Southgate.* (Abs.) 578

REVIEWS (See Book Reviews)

**Safety**
Digester Gas Explosion at Monroe, Michigan. *Arthur J. Jennings* 529
Digester Gas Explosion at Traverse City, Michigan. *Gerald Forton* 733

SAND FILTERS (See Intermittent Sand Filters)

SANITARY DISTRICTS (See Administration)

SANITARY SURVEYS (See Stream Pollution)

SCREENING
Operation of Mechanical Screens, Grit Chambers and Clarifiers. *W. A. Darby* 289
Sewage Treatment at Military Installations. *National Research Council* 787

SCREENINGS DISPOSAL
Incineration of Fine Screenings at Niagara Falls, N. Y. *Edward J. Smith* 221

SEDIMENTATION
Clarifiers. *J. B. Kleven.* (Abs.) 784
Operation of Mechanical Screens, Grit Chambers and Clarifiers. *W. A. Darby* 289
Preaerated Raw Sludge Recirculation Increases Primary Sedimentation Efficiency at Denver. *C. P. Gunson* 1121
Research Relating to Sedimentation. *L. B. Escritt.* (Abs.) 773
Sedimentation and the Design of Settling Tanks. *Thomas R. Camp.* Discussions by *Norval E. Anderson, R. A. Mulholland, P. Charles Stein, Lynn Perry, E. Sherman Chase* and *Rolf Eliassen.* (Abs.) 1236
Sewage Treatment at Military Installations. *National Research Council* 787
Solids Removal as Influenced by Plant Design. *Thomas M. Riddick* and *Herbert O. Johnson* 419

SEPTIC TANKS
Controlled Septicity of Sewage. *W. Watson.* (Abs.) 577

SEWERS
Control of Sewer Usage at Detroit, Michigan. *Clyde L. Palmer* 1127
Design and Operation of Sewage Regulators. *Kenneth Fishbeck* 651
Design of Sewers to Facilitate Flow. *Thomas R. Camp* 3
Effect of Mining (Coal) Subsidence on Sewers and Sewage Disposal Works in the West Riding of Yorkshire. *J. H. Garner.* (Abs.) 1249
Los Angeles County Sanitation District Sulfide Control Report. *Richard Pomeroy* and *F. D. Bowlus* 597

SKIMMING TANKS (See Grease Removal and Disposal)

SLUDGE CONCENTRATION
Concentration of Sewage Sludge. Discussion by *C. R. Velzy.* (Abs.) 1240

SLUDGE CONDITIONING
Computing Coagulant Requirements in Sludge Conditioning. *A. L. Genter.* (Abs.) 580
Computing Coagulant Requirements in Sludge Conditioning. Discussions by *Paul D. McNamee, K. F[illegible]* and *Walter H. Brown.* (Abs.) 123[illegible]
Dewatering of Sewage Sludge by Coagulation and Vacuum Filtration. Part I. Laboratory Experiments. *J. M. Wishart, [illegible]* and *L. [illegible]* (Abs.) 7[illegible]

SLUDGE DEWA[illegible]
Dewatering, [illegible] and [illegible] Sewage Sl[illegible] *Velzy C[illegible]* [illegible]38
Dewat[illegible] agula[illegible] Vacuum Filtration. Part [illegible] Laboratory Experiments. *M. W[illegible]shar[illegible]* [illegible] and *L. K[illegible]* (Abs.) 765
Sludge Disposal Practices at Detroit. *Clarence W[illegible]* 212
Sludge Disposal Practices at Detroit. A Discussion. *L. V. Garvey* 21[illegible]
Sludge Disposal Practices at Detroit. A Discussion. *R. A. Greene* 2[illegible]

SLUDGE DIGESTION
Digested Sludge. An Aid to the Activated Sludge Process. *L. S. K[illegible]* 1[illegible]
Digestion Tank Scum. *Walter E. [illegible]* [illegible]
Effects of Copper-Bearing Wastes on Sludge Digestion. *H. T. Rudge* [illegible]0
Pilot Plant Digestion Experiments. *David Back[illegible]er.* (Abs.) [illegible]3
Purification of Domestic Sewage by Digestion. *Karl Viehl.* (Abs.) [illegible]5
Sewage Treatment at Military Installations. *National Research Council* 787
Sludge Treatment at Small Sewage Works. *L. B. Escritt.* (Abs.) 164

SLUDGE DISPOSAL
Monsieur le Vidangeur. *J. E. McKee* 534
Sewage Treatment at Military Installations. *National Research Council* 787

Wartime Treatment of Sewage and Sludge Disposal. *F. Oliver.* (Abs.) ... 1244

SLUDGE DRYING BEDS (See Sludge Dewatering)

SLUDGE ELUTRIATION
Sludge Disposal Practices at Detroit. *Clarence W. Hubbell* ... 212
Sludge Disposal Practices at Detroit. A Discussion. *L. V. Garrity* ... 215
Sludge Disposal Practices at Detroit. A Discussion. *A. L. Genter* ... 695
Sludge Disposal Practices at Detroit. A Discussion. *R. A. Greene* ... 219
Small Sludge Elutriation Plants. *A. L. Genter* ... 26

SLUDGE GAS UTILIZATION
Digester Gas for Automobiles. *Karl Imhoff* ... 17
Fuel Fertilizer and Calcutta Sewage Sludge. *P. C. Bose.* (Abs.) ... 575
Propulsion of Vehicles by Compressed Gas. *W. Parker.* (Abs.) ... 770

SLUDGE INCINERATION
Dewatering, Incineration and Use of Sewage Sludge. Discussions by *C. R. Velzy, George J. Schroepfer.* (Abs.) ... 1238
Digester Gas Explosion at Monroe, Michigan. *Arthur J. Jennings* ... 529
Gas Engine Power for Sewage Treatment Plants. *Allen J. Bardeen.* (Abs.) ... 1240
Sludge Disposal Practices at Detroit. *Clarence W. Hubbell* ... 212
Sludge Disposal Practices at Detroit. A Discussion. *L. V. Garrity* ... 215
Sludge Disposal Practices at Detroit. A Discussion. *A. L. Genter* ... 695
Sludge Disposal Practices at Detroit. A Discussion. *R. A. Greene* ... 219

SLUDGE UTILIZATION
Dewatering, Incineration and Use of Sewage Sludge. Discussions by *C. R. Velzy, George J. Schroepfer.* (Abs.) ... 1238
Fuel Fertilizer and Calcutta Sewage Sludge. *P. C. Bose.* (Abs.) ... 575
Investigation of Plant Growth Substances (Auxins) in Sewage Products. *C. A. Chaplin* and *C. J. Regan.* (Abs.) ... 1251
Preliminary Greenhouse Studies of Digested Sludge as a Fertilizer. *Herbert A. Lunt* ... 16
Preparation and Nature of Town's Refuse-Sewage Sludge Composts. *C. Bould.* (Abs.) ... 1251

STATISTICS
Some Fundamental Concepts in Expression of Loadings and Efficiencies. *G. M. Rideout* ... 641
Washington State Sewerage Systems and Sewage Treatment and Disposal Systems. (Abs.) ... 1255
Wisconsin Progress Report on Sanitary Engineering and Stream Pollution Control Activities 1942-43. *L. F. Warrick.* (Abs.) ... 783

STREAM POLLUTION
Authority of the Indiana Stream Pollution Control Board to Order Ohio River Pollution Abatement. (Abs.) ... 589
Disposal Plant to Alleviate Boston Harbor Nuisance. *Karl R. Kennison.* (Abs.) ... 1241
Effect of "Acid" Wastes on Natural Purification of the Schuylkill River. *Robert S. Chabb* and *Paul P. Merkel* ... 692
Federal Anti-Pollution Legislation Progresses ... 752
History and Legal Background of Stream Pollution Control in Indiana. *Robert Hollowell, Jr.* (Abs.) ... 760
Industrial Wastes and Stream Pollution. *Joseph L. Quinn, Jr.* (Abs.) ... 764
National Policy for Trade Effluents. *John Hurley.* (Abs.) ... 769
National Stream Pollution Control Activities. *W. H. Wisely.* (Abs.) ... 587
1945 Progress Report on Pollution of Oregon Streams. *Fred Merryfield* and *W. G. Wilmot.* (Abs.) ... 780
People of the State of California, Plaintiff v. City of Los Angeles *et al* Defendants. (Abs.) ... 781
Rational Examination of Stream Pollution Abatement. *Richard D. Heath.* (Abs.) ... 166
Stream Pollution in Oil Fields Lessened by Salt Water Disposal Systems. (Abs.) ... 389
Stream Pollution in the Blue River Basin. *Robert W. Heider.* (Abs.) ... 170
Stream Pollution in the Maumee River Basin. *Robert W. Heider.* (Abs.) ... 169
Stream Pollution in the Musconetcong River Basin. *Robert W. Heider.* (Abs.) ... 171
Stream Pollution in the Patoka River Basin. *Robert W. Heider.* (Abs.) ... 589
Stream Pollution in the Whitewater River Basin. *Robert W. Heider.* (Abs.) ... 170
Stream Sanitation. *G. R. Scott* ... 284
Wisconsin Progress Report on Sanitary Engineering and Stream Pollution Control Activities 1942-1943. *L. F. Warrick.* (Abs.) ... 783

SUPERNATANT LIQUOR (See Sludge Digestion)

**Tips and Quips** ... 122, 325, 556, 741, 1211

TRICKLING FILTERS
Control by DDT of Flies Breeding in Percolating Sewage Filters. *T. G. Tomlinson.* (Abs.) ... 1253
Control of Trickling Filter Flies with DDT. *John A. Cavolla* ... 208
Experiments with DDT in Filter Fly Control. *William C. Brothers* ... 181
Filter Fly Control by DDT ... 330
Sewage Treatment at Military Installations. *National Research Council* ... 787
Summary of Experience in the Operation of Standard Trickling Filters. *D. E. Dreier* ... 704
Treatment of Camp Sewage and Laundry Waste Water by Alternating

Double Filtration. *E. V. Mills, J. T. Calvert* and *G. H. Cooper.* (Abs.) ..... 348
Treatment of Settled Sewage by Continuous Filtration With Recirculation of Part of the Effluent. *E. V. Mills.* (Abs.) ..... 776
Treatment of Settled Sewage in Percolating Filters in Series with Periodic Change in the Order of the Filters. *E. V. Mills.* (Abs.) ..... 777
Treatment of Sulfite Waste Liquor on High Rate Trickling Filters. *E. G. Tyler, William Maske* and *Robert Brewer* ..... 1155
Trickling Filter and Its Operation. *Frank Woodbury Jones* ..... 89
Trickling Filter Treatment of Sulfite Waste Liquor. *J. M. Holderby* ..... 671

**Vacuum Filters** (See Sludge Dewatering)

VENTILATION (See Safety)

# Index by Place

## Sewage Works Journal, Volume XVIII, 1946


**Akron,** Ohio 89, 99
Allentown, Pa. 99
Amersfoort, Holland 19
Anaheim, Calif. 511
Annapolis, Md. 30, 33, 35
Ann Arbor, Mich. 552
Atlanta, Ga. 210
**Belgrave,** N. Y. 420
Berlin, Germany 19
Brooklyn, N. Y. 89
Buffalo, N. Y. 51, 319, 511
**Calcutta,** India 575
Calistoga, Calif. 449
Camp Fannin, Texas 181
Cleveland, Ohio 89, 113, 121, 533, 543
Clifton Heights, Pa. 100
Cochrane, Ontario, Canada 581
Columbus, Ohio 89
Cranston, R. I. 29, 37
Crows Landing, Calif. 552
**Davis,** Calif. 456
Denver, Colo. 1121
Detroit, Mich. 212, 536, 1127
District of Columbia 1266
**East Boston,** Mass. 100
Elizabeth, N. J. 66, 67, 70, 73, 77, 80
Elyria, Ohio 528
Erie, Pa. 99
Essen, Germany 19
**Fallon,** Nev. 451
Fort McPherson, Ga. 208
Fort Wayne, Ind. 586
Fostoria, Ohio 100
Fullerton, Calif. 511
**Gary,** Ind. 325
Gastonia, N. C. 99
Gloversville, N. Y. 89
Green Bay, Wis. 1208
Greenwich, Conn. 125, 126
**Hamburg,** Germany 19
Hanover, Pa. 100
Hartford, Conn. 29, 39, 41, 47, 50
Holle, Germany 19
Hollister, Calif. 451
Ithaca, N. Y. 1138
Kenosha, Wis. 1130
**Lancaster,** Pa. 99, 101
Lansing, Mich. 19
LaPorte, Ind. 585
Louisville, Ky. 6
**Marion,** Ind. 28, 317, 584
Marshalltown, Iowa 548
Midland, Michigan 311
Milwaukee, Wis. 18, 98
Monroe, Mich. 529
Muncie, Ind. 586
Munich, Germany 19
Muskegon Heights, Mich. 101
**New Brunswick,** N. J. 511
New Haven, Conn. 46, 47, 50, 53
Niagara Falls, N. Y. 221
Nkana, Northern Rhodesia 1151
Norristown, Pa. 99
North East, Pa. 99
**Onondaga,** N. Y. 459
**Pasadena,** Calif. 554
Paterson, N. J. 98
Peoria, Ill. 1099
Peru, Ind. 585
Philadelphia, Pa. 89
Pittsburgh, Pa. 100
**Racine,** Wis. 54, 55, 61, 62
Reading, Pa. 89
Richmond, Ind. 586
**San Diego,** Calif. 12
San Francisco, Calif. 39
Santa Rosa, Calif. 452
Shoemaker, Calif. 437
Sioux Falls, S. Dak. 1145
South Baltimore, Md. 27
Springfield, Mass. 29, 30, 36, 39, 100
Stamford, Conn. 37, 42
Stuttgart, Germany 19
**Toledo,** Ohio 555
Tonawanda, N. Y. 193
**Vacaville,** Calif. 433
**Washington,** D. C. 29, 39, 99
West Haven, Conn. 104
West Pittsburgh, Pa. 100
Willow Run, Mich. 199
Winnipeg, Manitoba, Canada 1202
Worcester, Mass. 89